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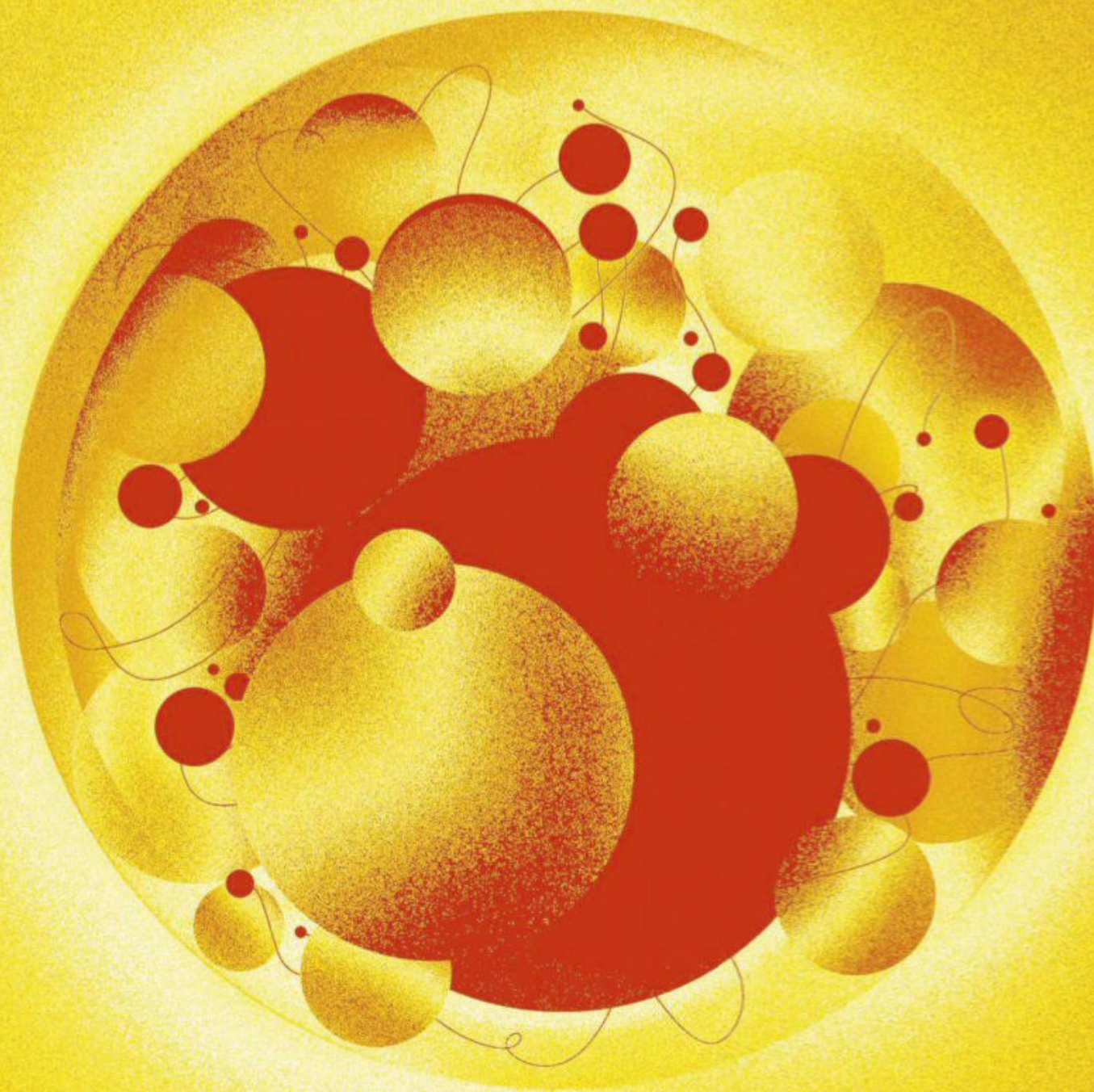
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HOW TO SAVE THE PLANET

Anti-vaxxers and
MEASLES OUTBREAKS

The robots that reveal
HOW DINOSAURS MOVED

THE BIG BANG WASN'T THE BEGINNING

How we'll find out what came before



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Semenya**

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give her an advantage

Heatwaves

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change shifting
our seasons?

SpaceX

What's next
for human
spaceflight?

**Natural
disasters**

What an 'act of God'
looks like in the lab

Junk food

Michael Mosley
reveals just how
bad it is for you



Conventional wisdom has been around for ages, but people forget to challenge what it means. Or why we continue to repeat it.

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Watched
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do boil

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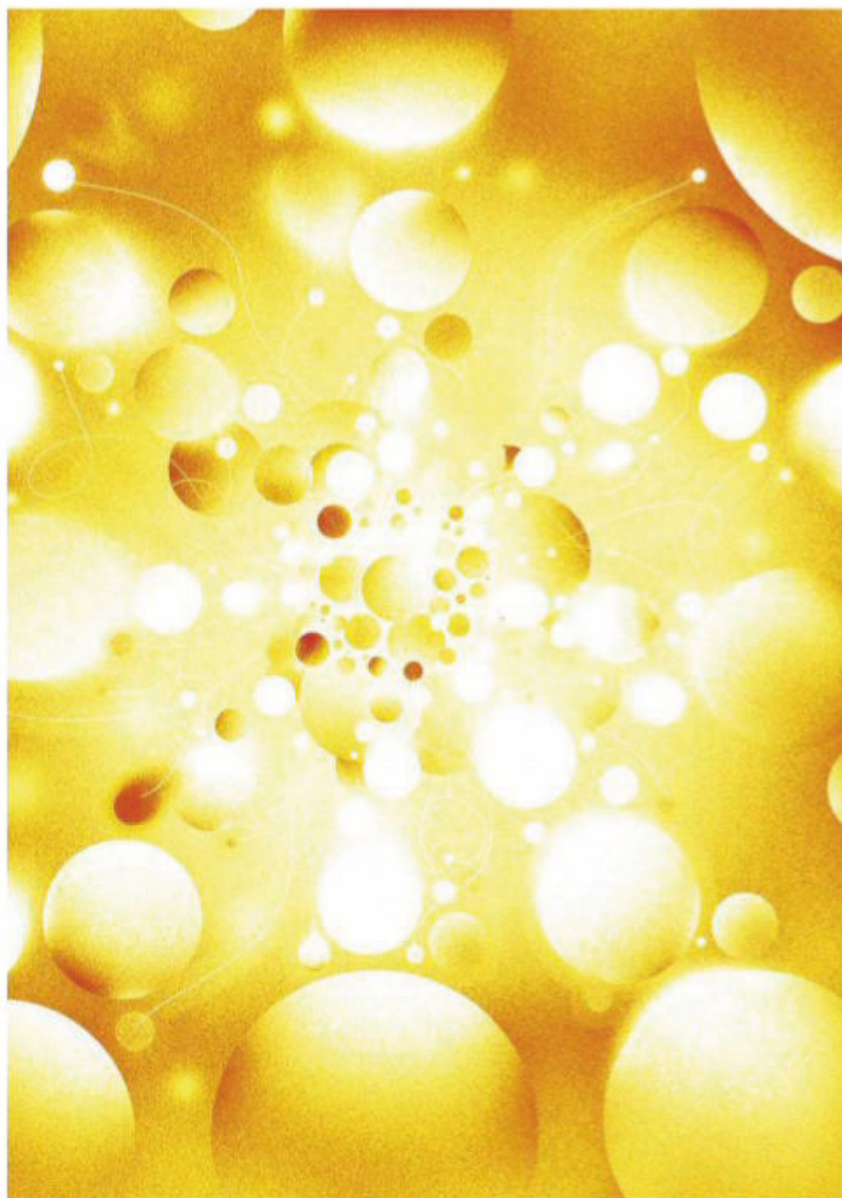
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“When you look down there are 500 different species, just there, and you’ve never seen anything like it”

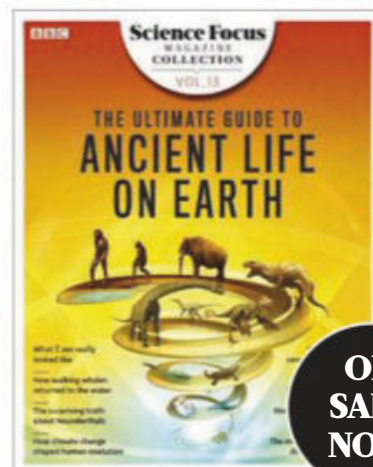
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→
Can anything really fly
without wings? p85

FROM THE EDITOR



At a certain scale, the Universe is a pretty tidy place. This isn't just a brilliant excuse to put off the spring cleaning, but a problem that physicists have been working on for the last 20 years. The Universe, specifically the amount of heat and matter in it, is spread out evenly. Too evenly, in fact, to be accounted for by our existing models of physics. For decades, this neatness has been attributed to the idea of inflation: a period where gravity, matter and energy behaved in bizarre yet plausible ways, giving rise to a Universe where everything is uniformly spread out. But now some physicists are beginning to ponder whether there might be another way to explain how it all began. The brilliant Marcus Chown helps us navigate their work on p70.

Looking a little less further back in time is palaeontologist Darren Naish, who's taken a detailed look at the mind-blowing project to turn the fossil of a creature that lived before the dinosaurs into a robot. The team's goal is to understand how some of the earliest known creatures moved. Get the full story on p52 and watch the OroBOT strut its stuff here: bit.ly/orobot_1

Daniel Bennett

Daniel Bennett, Editor

WANT MORE? FOLLOW SCIENCEFOCUS ON FACEBOOK TWITTER PINTEREST INSTAGRAM

ON THE BBC THIS MONTH...

TV

Look out for *Earth From Space*, narrated by Chiwetel Ejiofor, on BBC One, beginning in April



Radio

Hear medical ethicist and cancer patient Prof Deborah Bowman discuss patient autonomy on BBC Radio 4 (11am, 16 April)

iPlayer

Catch up on *BBC Science Focus* columnist Michael Mosley's attempts to get fit in *The Truth About...*

Sounds

Listen to the scientists trying to solve the mystery of how placebos work... bit.ly/placebo_paradox

CONTRIBUTORS



SIR DAVID ATTENBOROUGH

The greatest voice on Earth talks about his new show *Our Planet* and why, despite imminent climate chaos, he's still hopeful for the future. → p60



DR SUZANNE GAGE

Suzi, who studies the relationship between recreational drugs and behaviour, examines whether the online world is turning us all into addicts. → p78



DR ALEKS KROTOSKI

The way we talk about leprosy needs to change, argues Aleks, who grew up around people suffering from what's known medically as Hansen's disease. → p68



PROF PETER SONSSEN OBE

A retired professor of endocrinology, Peter developed the test to detect growth hormone abuse for the London Olympics that caught two athletes. → p40

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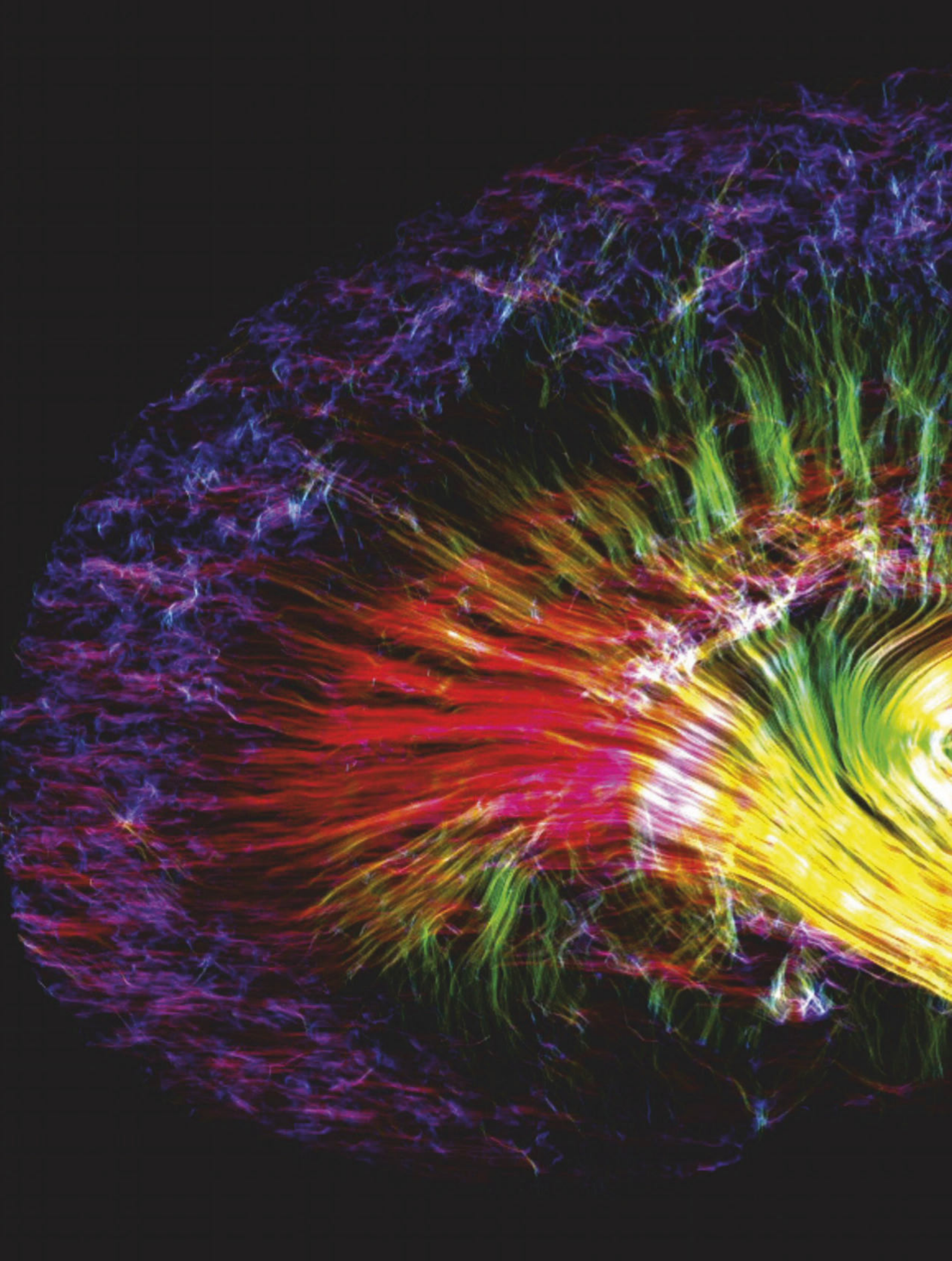
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EYE OPENER

Vibrant fibres

DUKE UNIVERSITY, USA

This rainbow explosion is a map of a mouse kidney, as revealed by diffusion tensor imaging (DTI) – a type of magnetic resonance imaging. DTI tracks the motions of water molecules as they pass through the fine tubes inside the kidney. The fluid that travels through these ‘tubules’ has nutrients removed and waste products added as it’s turned into urine.

The colours of the fibres in this image represent their orientation, building a three-dimensional representation of the architecture of the kidney.

MRI scans produce images by applying strong magnetic fields to tissue, and can be performed safely on living organisms. This photo is the winner of 2018's BMC Research In Progress photo competition.

NIAN WANG

VISIT US FOR MORE AMAZING IMAGES:

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EYE OPENER

Bat cave

TEXAS, USA

Bracken Cave, outside San Antonio, Texas, hosts the world's largest maternity bat colony.

Over 15 million Mexican free-tailed bats, most of them pregnant females, roost in the cave during the summer months. Towards the end of June, the cave's population almost doubles as each expectant mother gives birth to a pup.

The pups' energy demands are so high that the mothers have to eat their own body weight in insects every 24 hours in order to produce enough milk to nurse them. So every night, shortly before sunset, there is a mass exodus from the cave as the mothers head out to hunt. When the mothers return, they find their young among the millions of others in the nursery by scent and vocalisations.

KARINE AIGNER/NATUREPL.COM

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*



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LETTER OF THE MONTH

Dancing poles

I read with great interest the article about the magnetic poles moving in the March issue of *BBC Science Focus* (p28). It reminded me of a question that pops into my mind whenever I come across a mention of the magnetic north pole.

We are all taught that opposite poles attract each other and like poles repel. Why is it then that, ignoring deviation, the north pole of a magnet or compass points to geographic north? Surely either the Earth's magnetic north pole is in the southern

hemisphere or our magnets have north and south wrongly identified. The article states that magnetic north is near geographic north, somewhere over Canada, so something must be amiss.

Also, when we draw lines of magnetic flux from the north pole of a magnet to the south pole, how would they be drawn for Earth's magnetic field?

Ian Newton, physics technician,
St. Swithun's School

You're right, Ian – technically the magnetic north pole is like the south pole on a magnet. But we used to call the tip of a compass needle the 'north-seeking pole' because it pointed to the geographical north pole, so it became known as the magnetic north pole. As for the lines of magnetic flux, you can approximate Earth's axis as a bar magnet with its south pole as the magnetic north pole and its north pole at the magnetic south. In reality, it's more complicated than that (especially as the poles are moving), but it's a decent approximation.

Sara Rigby, online assistant



WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **Blink**, the completely wireless, one camera, indoor home security solution that sends motion activated alerts and high definition video to your smartphone. Blink is easy to install and lasts for up to two years on only two AA batteries.

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Good with faces?

As we enter more deeply into the age of the algorithm, technology is advancing at a pace so rapid that it's easy to imagine it running ahead of human control.

One area where technology is already progressing at such a rate is facial recognition systems, which are often criticised in the media due to their ostensibly high error rates. I expect many of your readers will have experienced some sort of drama while using an airport's e passport gate. A solution to this issue is to ensure that we retain skilled humans as the ultimate verifiers of the technology's function, correcting any errors and maintaining a credible decision making process. These people are essential for maintaining security at borders and ensuring that human rights and freedom of movement are not violated.

The issue of human oversight becomes even more vital if you substitute automated facial recognition at border controls for automated facial recognition in combat zones. If the decision is related to a suspected armed terrorist observed from a UAV then it could become a matter of life or death.

I work with a group of 'super recognisers', people who are graced with an amazing memory for human faces – it's estimated that only 1 per cent of the population are born with such skills. Online tests are now available to find this gifted minority. Their abilities are being recognised globally with Scotland Yard maintaining a small super recogniser cell, Germany recently establishing

one and other nations examining the possibilities that super recognisers offer.

With artificial intelligence and machine learning playing an ever increasing role in our lives, we must not to forget to ensure that human beings retain ultimate control in order to provide the ideal man/machine solution. Without it I fear that potentially avoidable tragedies resulting from an over reliance on technology will become the new norm.

Jeff Little OBE, via email

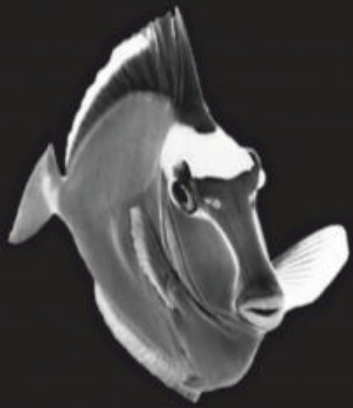
I'm fine sitting, thanks

I recently read Michael Mosley's article in your March issue of *Science Focus* and found one item lacking from the study.

There seemed to be quite a lot of detail surrounding the health benefits of standing desks and how fast glucose was being processed. But there was no reference, with the exception of an anecdotal comment by the author, regarding the impact of standing desks on the ability to perform the tasks of the day.

I am a control engineer with a configurable standing/sitting table for my laptop and can stand and sit whenever I need. While I find that standing often improves my immediate motivation to get stuck in and to be more dynamic, it wears quickly and I get tired shifting from one foot to another. When I sit down, however, I can focus more deeply and get a better understanding of the problems that I'm trying to solve.

I believe that a lot of studies seem to revolve around health



“I CAN’T THINK OF A MOMENT THAT HAD MORE EFFECT ON ME THAN THE FIRST TIME I DIVED WITH AN AQUALUNG ON THE BARRIER REEF”

SIR DAVID ATTENBOROUGH, p60

benefits but not as much surrounding benefits of focus and concentration.

Alan Curley, via email

Time to read

Thank you for printing Graham Pollard’s question about the existence of gravitons in your March issue’s Q&A section. I am Graham’s wife – Graham sadly passed away in February 2019. What a waste of a fantastic mind! He had a brain tumour that limited his mobility. But, as a plus, it meant he got back all the time he never had prior to his diagnosis at the age of 66, so he was able to read and read. I am so proud of him for having his question printed in *BBC Science Focus* – thank you for giving it such prominence. Graham would have been so happy, but knowing him, he’d have been very understated about it!

Gail Pollard, Saddleworth

Glass half empty

The Hidden Power Of The Brain (March, p60) article got me thinking about whether being happier really is better for us when it comes to managing stress. While I’m sure most people would rather be called an optimist than a pessimist, sometimes expecting the worst can be better for you because when the bad news comes, you’re already braced for it.

A good example of this is Adam Kay’s book *This Is Going To Hurt*, about his experiences as a junior doctor. While Kay maintains a positive outlook throughout most of the story,



when disaster strikes, it affects him much worse than I believe it would have done if he’d been expecting the worst.

So the question we have to ask is whether it’s better to be

I must admit, it didn’t look like my type of magazine, but I didn’t want to appear rude so I accepted her offer. I was surprised to find it contained a number of really interesting

“IS IT BETTER TO BE HAPPIER, BUT LESS PREPARED TO DEAL WITH PROBLEMS?”

happier, but less prepared to deal with problems when they arise; or whether it’s better to be gloomier, but geared up for when things don’t work out?

Nathan Burn, Salisbury

Mag’s best friend

A colleague recently offered me her copy of *BBC Science Focus* to read one lunchtime, after I realised I’d forgotten my book.

articles, but my favourite was the news story about dogs and diabetics (February, p26). I found it remarkable that dogs can sniff out cancer and other medical conditions.

With all the negativity in the press at the moment, I found it inspiring to see the positive impact science has on the world. I enjoyed reading *BBC Science Focus* so much that I’ve decided to subscribe.

Sue Cawte, Essex

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P1970A



INCOMING MISSILE!

When faced with disaster, don't panic, tweet! **p22**

MAN'S BEST MATE

Wolves are what make dogs happy to help **p23**

OOH OOH AAH AAH

Chimps' language is similar to ours **p28**

FANCY A LAUGH?

Comedians are needed on Mars missions **p30**

DISCOVERIES

Actors' brain activity changes when in character

Brain imaging study finds that actors' sense of self fades away while they are performing

It seems it really is possible for actors to lose themselves in a role. Activity in a part of the brain associated with self-knowledge and self-perception drops off when actors are performing, researchers from the NeuroArts Lab at McMaster University, Canada, have found. The finding suggests that playing the part of another character results in a loss of self, they say.

The study focused on a group of 15 third and fourth year theatre studies students recruited from McMaster University, all trained in 'method acting' – an approach in which actors

Running the numbers Marathon times **p26** **Beaky bird** Fossil of first known perching bird found **p32**
Crew Dragon What SpaceX's recent mission means for space travel **p25**

News in brief

WANT TO AVOID THE WINTER SNIFFLES? GET YOUR FLU JAB IN OCTOBER

As the protection offered by the flu jab slowly wanes as the season progresses, it may be best to wait a little before getting your flu jab, a study at the University of Pittsburgh has found. The team ran computer simulations and determined that getting the jab in October offered the most protection. However, getting vaccinated is always better than not getting vaccinated, whatever the time of year, the researchers said.



aspire to fully embody the emotions of their characters, which has been widely popularised by icons like Marlon Brando, Robert De Niro, and Daniel Day-Lewis.

The team, led by Steven Brown, placed each of the actors into an MRI scanner a total of four times and scanned their brain activity while they answered a series of questions. Each time they were randomly tasked with answering the questions in a different way: as themselves, as themselves but in a British accent, as a close friend, or as if they were playing the part of Romeo or Juliet in Shakespeare's famous play.

Usually in such studies Brown's team looks for increases in brain activity when performing tasks that differ from the control (in this case, answering questions as themselves). But the researchers found that activity in certain areas of the brain actually dropped when the students were answering as Romeo or Juliet.

"Instead we found mainly deactivations or reduction in the level of activity in the brain compared to when they were answering questions as themselves," said Brown. "The major area where we found these reductions was the dorsal medial

prefrontal cortex. It's a part of the brain that is definitely involved in self-processing, especially knowledge of one's own physical or personality traits."

However, they also found increased activity in the precuneus, a part of the brain that is associated with attention.

"Actors have to divide their attention between themselves and the character and so we think this activation increase may reflect something about the split consciousness or divided attention that actors have to bring to the role," said Brown. "Where they have to be the character but still monitor the fact that they are themselves. Especially if you are walking around on stage where you don't want to bump into the furniture."

There are, as yet, no planned clinical applications of the findings, but Brown says it could perhaps help us to understand how therapies involving roleplay can prove effective in treating sufferers of anxiety or PTSD, or helping couples to understand each other's viewpoints in relationship counselling.

For the latest science news, visit sciencefocus.com



WHAT IS fMRI?

Functional Magnetic Resonance Imaging (fMRI) shows what the brain is doing, as well as how it looks. Volunteers in fMRI experiments typically carry out some kind of cognitive task – responding to stimuli or calculating, recalling or imagining something – while the scanner measures the blood flow to and from different parts of their brain and superimposes it on an anatomical picture of the brain (similar to an X-ray image). The areas pulling in most blood are assumed to be those that are most active. This is because blood carries oxygen, which is the 'fuel' that brain cells use to generate electricity.

fMRI is the most common technology used to correlate brain activity with our thoughts, responses and perceptions because it seems to be safe and it is good at pinpointing location. Other techniques, for example, non-invasive EEG, in which scalp-mounted electrodes detect signals from the underlying brain, are faster but less precise.

'OLDER' SPERM PRODUCE HEALTHIER BABIES

In an experiment involving zebrafish, a team at the University of East Anglia found that longer-lived sperm produced healthier offspring than shorter-lived sperm, even when taken from the same sample produced by the same male.



They did what?

Night vision given to mice

WHAT DID THEY DO?

Scientists have given 'night vision' to mice, allowing them to see infrared light. A team based at the University of Science and Technology of China has found that injecting small amounts of specially designed nanoparticles into the animals' eyes enabled them to see infrared light for up to 10 days.

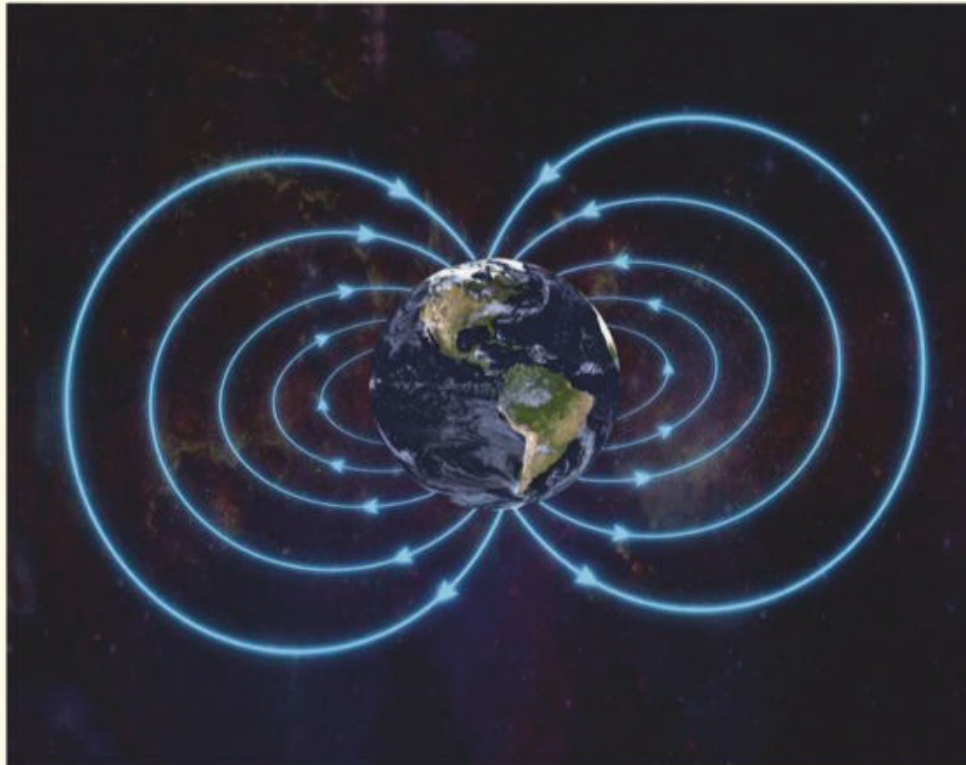
The vision of humans and other mammals is limited to a specific range of wavelengths of light known as visible light. Infrared radiation has a longer wavelength than this and is emitted by people, animals and objects as they give off heat. It is what is picked up by the thermal imaging cameras used by everybody from secret service members to wildlife researchers.

WHAT DID THEY FIND?

The injected nanoparticles act as 'translators' that bind to light receptors in the retina allowing them to see infrared light. The nanoparticles capture the longer wavelengths of infrared light and then transmit them at shorter wavelengths in the visible range. The light receptors then absorb the shorter wavelength and send a signal to the brain as if they were perceiving visible light.

WHY DID THEY DO THAT?

The team believes that the technique would work on humans and could lead to treatments for those with difficulty seeing colours at the red end of the spectrum, or even allow those with regular vision to see a wider range of wavelengths.



The Earth's magnetic field is detectable by birds, fish... and maybe even humans

HUMANS

Humans may have an ancient magnetic sense

Our bodies appear to have their own tiny, internal compasses

Humans may have a sixth sense called magnetoreception – the ability to sense Earth's magnetic field. It's one of the ways birds and fish are able to navigate huge distances with surprising accuracy: a built-in compass for journeys across the globe. But until now, it hadn't been seen in humans.

Researchers from the California Institute of Technology and the University of Tokyo searched for this ancient sense by recording the brain waves of 29 participants using electroencephalography (EEG).

The participants sat inside a Faraday cage, which blocks all electronic and magnetic interference, and the researchers used electric coils to create artificial magnetic fields. When the magnetic field was changed, participants experienced a drop in their brains' alpha-rhythms – a phenomenon

often seen when our senses are stimulated, be it vision, hearing, or touch. This told the researchers that the participants' brains were perceiving this change in magnetic field.

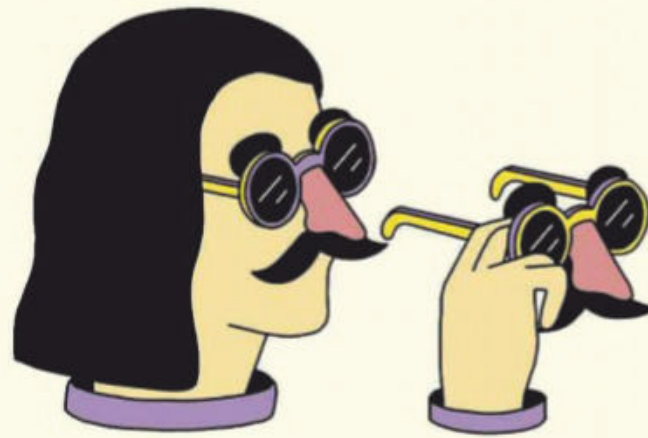
This could be due to magnetite – iron crystals found in human cells, including in the brain – being affected by the Earth's magnetic field like tiny compass needles.

"Many animal tissues make tiny magnetic crystals," said study leader Joe Kirschvink. "The best example is the magnetotactic bacteria. There's enough magnetite in their cells to passively torque them into alignment with Earth's magnetic field."

The participants couldn't consciously perceive the changes in field strength. This could mean that our magnetosensory systems are lacking a component that allows us to consciously perceive it.

SIMPLE DISGUISES WORK WELL

Superman was onto something: a simple change of appearance, such as a pair of glasses, is effective at hiding your identity. Such a disguise can reduce people's ability to correctly match faces in photographs by 30 per cent, according to a study at the University of York.



Trending

YOUR GUIDE TO WHO'S SAYING
WHAT ABOUT THE HOTTEST TOPICS
IN THE WORLD RIGHT NOW

#web30

On 12 March 30 years ago, Tim Berners-Lee (below) submitted a memo titled *Information Management: A Proposal* to CERN management, laying down the foundations for the World Wide Web.

CERN

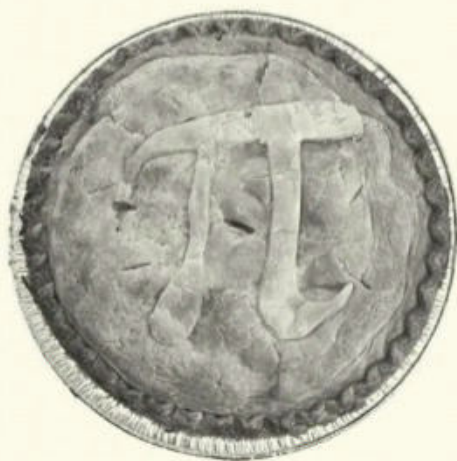
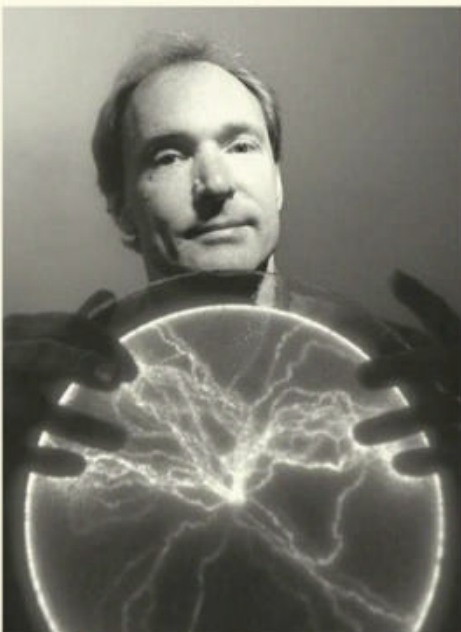
@CERN

#Web30 Thirty years ago, an unimaginably powerful tool was invented by Sir Tim Berners-Lee here, at CERN.

Jimmy Wales

@jimmy_wales

In 2001 @Wikipedia was launched. Thank you to the millions of Wikipedians who have contributed to the web's biggest encyclopedia over the last 18 years. #Web30 #ForTheWeb



#PiDay

Pi Day is an annual celebration of the mathematical constant observed every year on 14 March as the first three digits of the date are 3, 1 and 4. It was first organised by physicist Larry Shaw at the San Francisco Exploratorium in 1988.

NASA

@NASA

Pi is the Swiss Army knife of numbers. No matter how big or small a circle — from the size of our Universe, all the way down to an atom — the ratio of a circle's circumference to its diameter is always pi. #PiDay

Google Cloud

@GCPcloud

31.4 trillion: the number of π digits calculated. Congratulations to @Yuryu, who set the new world record, calculating almost 9 trillion more digits than the previous world record using Compute Engine VM clusters

#StephenHawking

14 March marked one year since Theoretical physicist Stephen Hawking passed away at the age of 76. To mark the day, the Royal Mint announced that it will be releasing a commemorative 50p coin featuring a black hole and Hawking's equation for entropy of a black hole.

Gonville & Caius College

@CaiusCollege

It is great to see the work of Professor Stephen Hawking, a Fellow of @CaiusCollege for over 50 years, commemorated on a new 50p. The coin features a big #blackhole, and the late Professor's famous equation for '#Hawking #Entropy'

Joe Plumb

@thejoeplumb

"Remember to look at the stars and not at your feet. No matter what life may bring, don't just give up." #StephenHawking 1 Year Today! R.I.P Gone but not forgotten

Ray Caruso

@Ray1Caruso

"Although I cannot move, and I have to speak through a computer, in my mind, I am free." – Stephen Hawking #Quotes #StephenHawking #Science #Freedom



#GretaThunberg

The 16-year-old Swedish climate activist (above) that founded the Youth Strike 4 Climate Change movement has been nominated for the Nobel Peace Prize.

George Monbiot

@GeorgeMonbiot

@GretaThunberg would be a wonderful Nobel Peace Laureate. I support her nomination, and hope it succeeds.

Amy Kothari

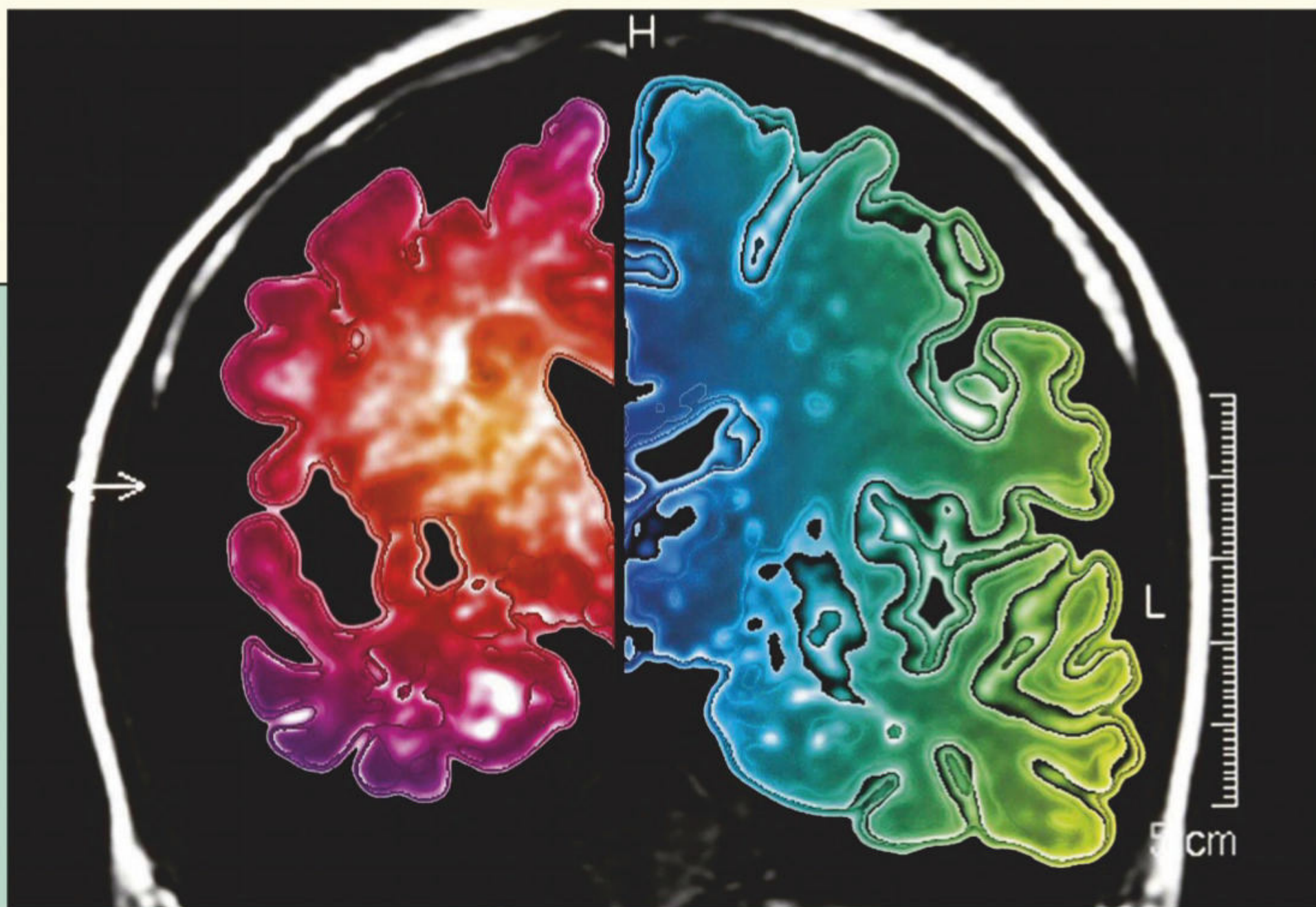
@the_real_amyk

In 2 days, students in 82 countries (including our own) will be walking out of school to protest global inaction on #climatechange thanks to the organising of Swedish teen #GretaThunberg they deserve our attention&support

KEEP IN TOUCH



@SCIENCEFOCUS



NEUROSCIENCE

Diet can help keep dementia at bay

Early findings suggest green tea and carrots can play a part in fighting Alzheimer's disease



Researchers at the University of Southern California (USC) have used compounds found in green tea and carrots to reverse Alzheimer's-like symptoms in mice.

The study also supports the idea that a combination of therapies, rather than a single 'magic bullet', may be the best way to treat Alzheimer's disease.

The team genetically altered 32 mice to develop Alzheimer's-like symptoms and split them into four groups containing an equal number of healthy mice. They fed the mice on a diet of epigallocatechin-3-gallate (EGCG), a key ingredient in green tea, ferulic acid (FA), found in carrots and tomatoes, or a placebo. Before and after being put on the diet, the mice went through a series of neuropsychological

tests similar to those used to assess dementia in humans.

Before the diet, the mice with Alzheimer's-like symptoms struggled with the tests. But afterwards they were able to perform as well as their mentally healthy counterparts.

"After three months, combination treatment completely restored [the mice's] working memory," Prof Terrence Town of USC said. It's thought the EGCG and FA prevent large proteins in the mice's brains from breaking down into smaller substances called amyloid beta plaques, which interrupt the activity of neurons in those with Alzheimer's. The team now plans to search for other dietary sources that inhibit amyloid beta plaques.

CREATURES IN OCEAN TRENCHES ARE STUFFED WITH PLASTIC

UK-based researchers studied tiny crustaceans called amphipods taken from six ocean trenches at depths from 7,000m to 10,890m. They found that 65 of the 90 animals studied had all eaten at least one piece of plastic. Animals from the Mariana Trench – the world’s deepest – contained the highest average number of particles.



SOCIAL MEDIA

Missile threat? Don't panic, tweet

Last year's false missile alarm in Hawaii offered insights into our behaviour...

Imagine receiving this text message: 'Ballistic missile threat inbound to Hawaii. Seek immediate shelter. This is not a drill.' What would you do?

According to a new study by researchers at the University of Georgia, you wouldn't panic, nor would you seek shelter. You'd go on Twitter.

When a similar scenario happened in Hawaii in January 2018, rather than panicking or rushing to seek shelter, the majority of locals turned to either social media or major news outlets in order to verify the message. They were trying to find out more information about the warning, which was confirmed to be a false alarm 38 minutes later. This type of search for information is known as 'social milling', and it's a way of finding all the necessary detail to make the right decision about what to do next. "It's getting a sense of what other people are doing," said Sarah DeYoung, an assistant professor in the Institute for Disaster Management at the University of Georgia's College of Public Health. "Social milling means, let's see what's going on, observing the scene but also checking in with others."

For the study, the researchers surveyed Hawaiian residents about how, among other things, they perceived the level of risk of a missile threat, and what actions they took once they saw the warning.

The 'social milling' approach was effective; Hawaii congressional leader Tulsi Gabbard was quick to tweet that the warning was an error; a tweet that 16 per cent of survey responders saw and retweeted to their networks.

DeYoung, who authored the study, spoke about the value of social media for



spreading important information: "those who [saw the message] were able to deliver that message to their immediate network of people."

DeYoung notes that people wanted multiple cues to validate the warning, and suggests that in the future official messages should go out across more than one channel of communication, as this tends to increase people's level of belief and trust in the warning.

Trouble in paradise: in 2018, Hawaiian residents received text message warnings that a missile attack was imminent

6,000

Number of tweets sent every second



Fake news is 70 per cent more likely to be spread on Twitter than the truth



The average Twitter account has 707 followers

In numbers

32

The number of times more deadly ingesting party balloons is to seabirds than eating hard plastics, as found by researchers at the University of Tasmania.

50%

The amount that sperm quality has reduced globally over the last 80 years, according to a study at the University of Nottingham. The effect is largely due to environmental pollutants, the researchers say.

2 hours

The time it took 10,000 maggots to eat their way through a 16-inch Margherita pizza, as recorded by a team at Georgia Tech.



ANIMAL BEHAVIOUR

Wolves are what makes dogs so happy to help

Dogs might be man's best friend, but wolves give them a run for their money. Researchers at the University of Veterinary Medicine in Vienna have shown that wolves are just as willing to join forces with humans when given the chance.

To test the animals' cooperation, the scientists set up an experiment in which an animal and a human had to pull simultaneously on two ends of a rope to move a tray containing food. The experiments were carried out with dogs and grey wolves who had been raised at the Wolf Science Center in Ernstbrunn, Austria.

The researchers found that wolves and dogs were equally adept at working with humans, but wolves were more likely to come up with their own tactics to get the

food, such as stealing the rope from the human. "While wolves tend to initiate behaviour and take the lead, dogs are more likely to wait and see what the human partner does and follow that behaviour," said Dr Friederike Range, who led the study.

The researchers propose that it's 'the wolf within the dog' that has enabled pooches to cooperate with humans so effectively. Rather than gaining their cooperative skills during domestication, it seems dogs inherited them from their lupine ancestors.

It may be dogs' more submissive nature that explains why humans were able to domesticate them as pets. Dogs' tendency to follow our lead would have made it easier for us to work alongside them and accept them into our homes.

You can take the dog out of the wolf but you'll never take the wolf out of the dog

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Primer

Crew Dragon

IN EARLY MARCH, SPACEX SUCCESSFULLY SENT ITS CREW DRAGON CRAFT TO THE ISS, AND RETURNED IT SAFELY TO EARTH. WHAT DOES THIS HISTORIC MISSION MEAN FOR SPACE TRAVEL?

WHAT IS THE CREW DRAGON?

The Crew Dragon is SpaceX's first human-rated vehicle. Its design is based on the Dragon cargo module which SpaceX uses to run supplies to the International Space Station (ISS). In March, it went through its first flight tests in orbit, a step closer to NASA approving it for human flights.

When in operation, the Crew Dragon – along with rival Boeing's Starliner – will act as taxis, carrying astronauts to and from orbit. They were developed as part of NASA's Commercial Crew Development programme, which aims to provide a way to launch humans into space from US soil. Since the end of the Space Shuttle in 2011, NASA's relied on Russian Soyuz capsules to reach the ISS. As well as the political ramifications of the US being solely dependent on Russia, using a single transportation system is unreliable. This was highlighted in late 2018, when a series of issues led to all Soyuz spacecraft being grounded for several months. The issues were quickly solved, but the incident almost ended up with the ISS being abandoned for the first time since 2000.

WHAT COULD GO WRONG?

Space vehicles are made up of millions of different parts, but a single defective screw or washer can mean the difference between success and failure.

The trickiest parts of any space mission are launch and re-entry when the

spacecraft passes through the atmosphere at vast speed, subjecting craft and crew to extreme accelerations, temperatures and pressures. Though SpaceX has a lot of experience in launching and retrieving the similar Dragon craft, it was these stages of the test that most concerned company founder, Elon Musk.

It was possible that the docking procedure might go wrong, causing the spacecraft to crash into the ISS or damage the docking ring, or that the module might have an air leak. However, the spacecraft had undergone rigorous testing before leaving Earth and NASA would never have allowed the spacecraft near the ISS if it thought there was a genuine risk of either occurrence.



“SpaceX aims to make spaceflight accessible to more than just government agencies and the super wealthy”

HOW DID IT GO?

The test was a success. The craft launched on 2 March 2019 from Pad-39A – the same pad where almost all the Apollo and Space Shuttle missions blasted off.

For this first test, the spacecraft was in fact a Crew-less Dragon, as the only passengers were a mannequin covered in sensors (named Ripley after the hero of the *Alien* movie franchise) and a soft toy of Earth. With no human pilots onboard, the spacecraft operated entirely automatically and docked with the ISS on 3 March.

For four days, astronauts conducted tests confirming its safety. The spacecraft

undocked on 8 March, splashing down in the Atlantic Ocean before being picked up by SpaceX's recovery ship.

WHAT'S THE NEXT STEP?

Both SpaceX and Boeing (which is expected to make its own uncrewed test in the coming months) have a way to go before they can start routinely carrying passengers. First, they will have to demonstrate they can safely abort a launch at the last minute, in case of emergency. Then it will be time for the biggest test of all: the first human flights. Initially the spacecraft will be piloted by two veteran space explorers who will perform a similar mission to that which SpaceX performed in March. Once NASA is happy the spacecraft can carry humans, it will enter rotation as NASA's main method of transporting astronauts to the ISS.

NASA's goal has always been to forge the way into space so that citizens can follow. The aim of the Commercial Crew Development programme is not just to create a new method of getting people into space, but also to pass the baton of space travel from government hands into the private sector.

WHAT'S SPACEX'S ULTIMATE GOAL?

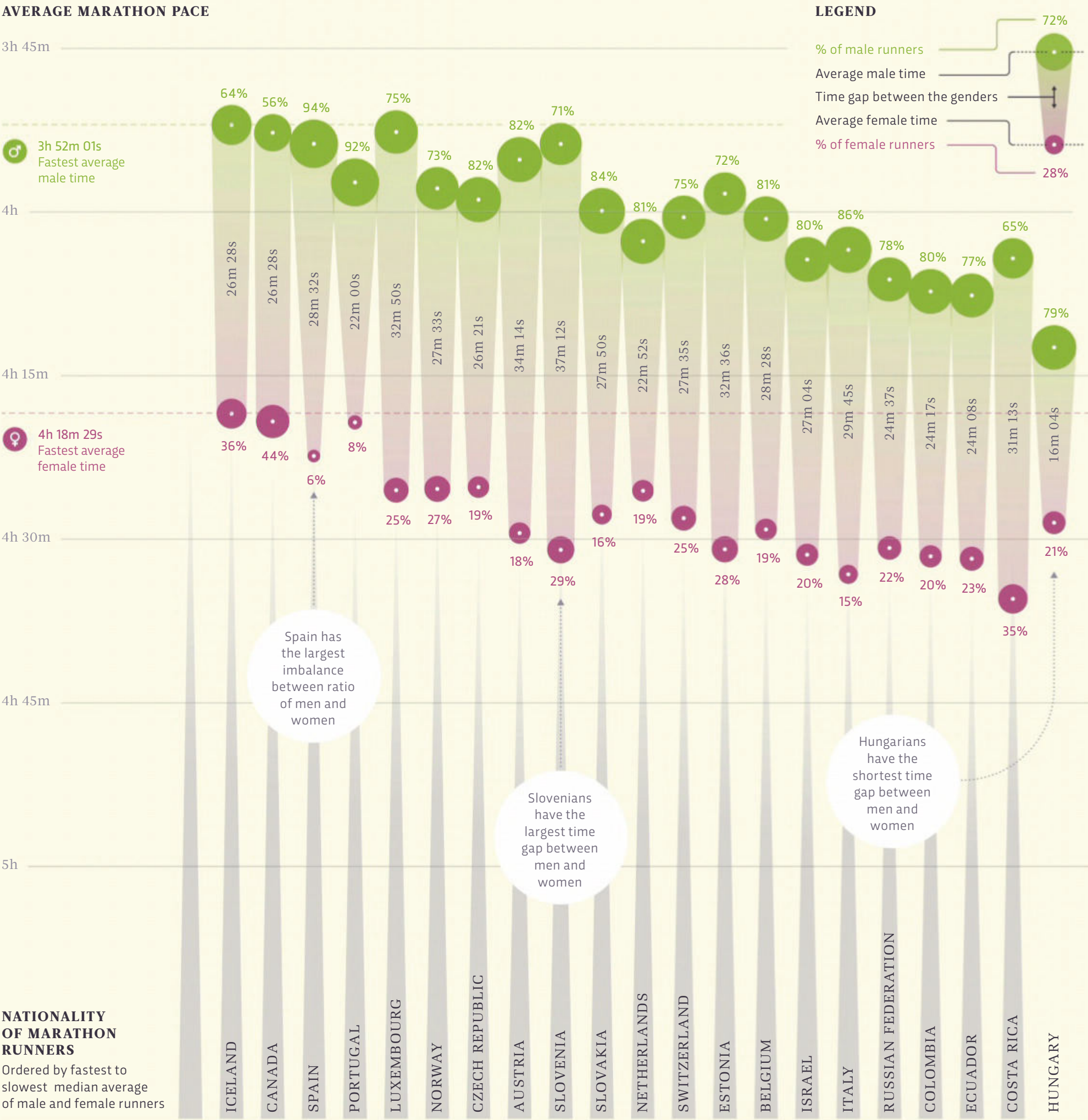
SpaceX aims to make spaceflight accessible to more than just government agencies and the super wealthy. The ultimate aim is to make the Crew Dragon completely reusable, which will drastically reduce the cost. Each spacecraft also contains seven seats, whereas the Soyuz can only hold three, and the high level of automation means that shorter training times are required. The spacecraft could soon be ferrying vast numbers of people to low-Earth orbit.

However, Elon Musk has often said his sights are set much further away than just orbit – he wants to take humanity to Mars. While Crew Dragon isn't capable of making that journey itself, it is a first step along the 55 million kilometre journey.

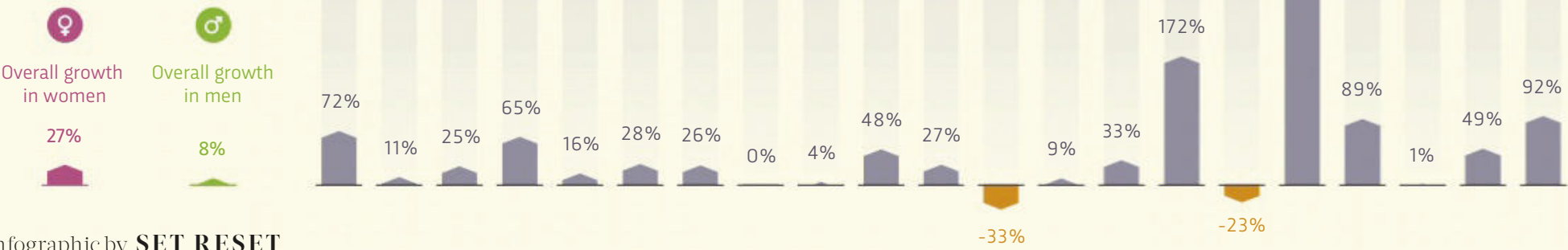
DR ELIZABETH PEARSON

Elizabeth is news editor at Sky At Night Magazine.

AVERAGE MARATHON PACE



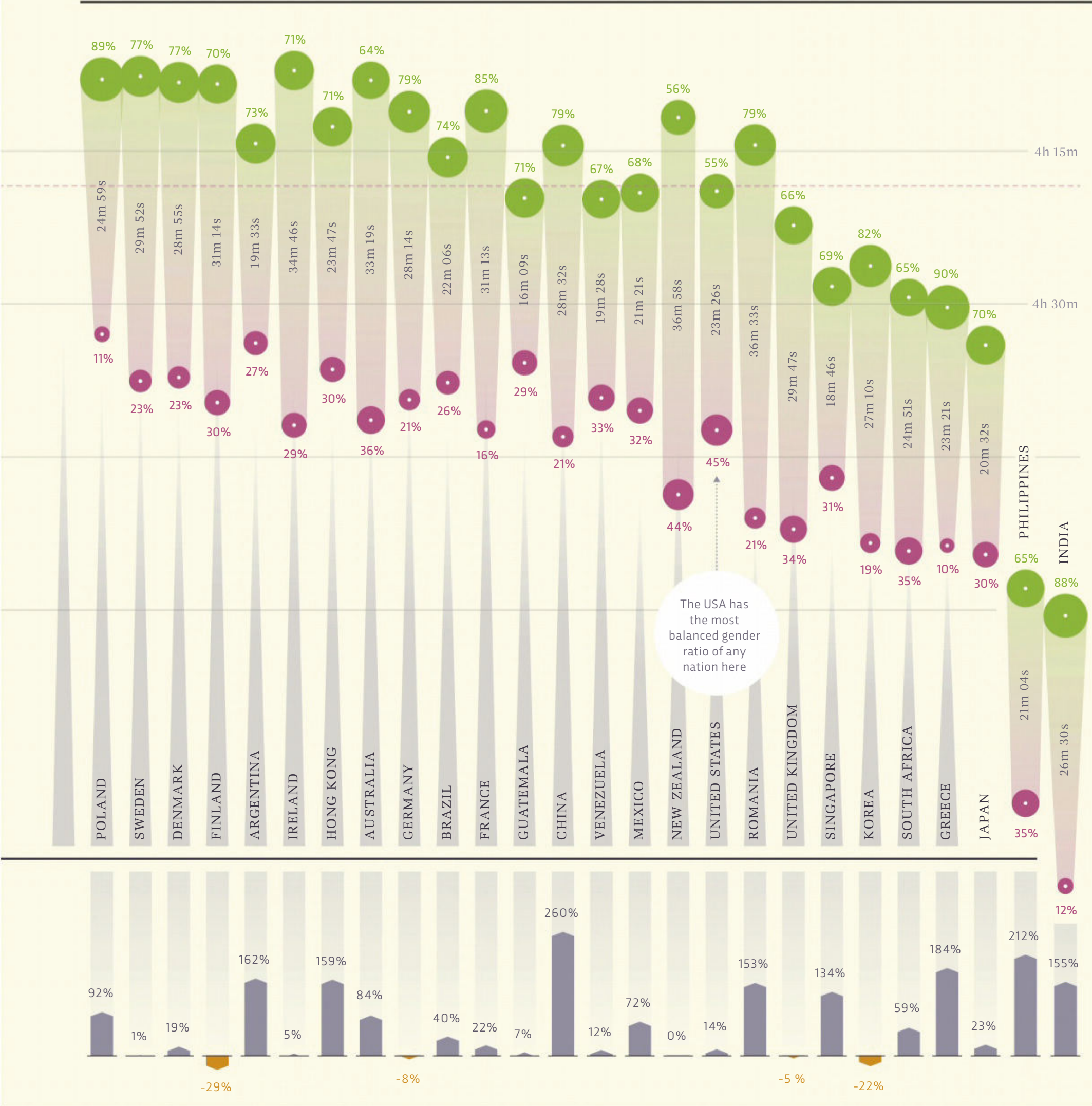
GROWTH OF MARATHON RUNNING 2009-2014

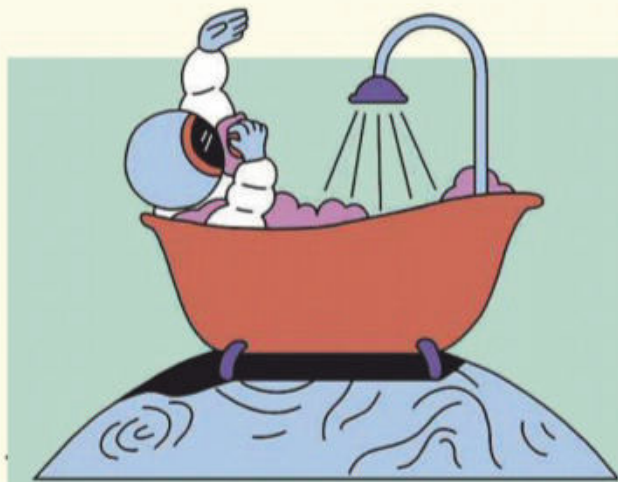


Data crunch

This year, 414,168 people are set to run the London Marathon. The likes of Ethiopia’s Kenenisa Bekele and Kenya’s Mary Keitany will be looking for times close to the two-hour mark. But this data, compiled from 72 marathons held between 2009 and 2014, will give you an idea of how quickly the amateur runners can expect to cover the 26.2 miles.

RUNNING THE NUMBERS





THIRSTY ASTRONAUTS

The solar wind may provide a water supply for future settlers on the Moon, says NASA. Protons carried by the solar wind (charged particles released by the Sun) interact with free electrons on the lunar surface to create hydrogen atoms. These latch onto oxygen atoms in the lunar soil to create H_2O .

DEATH METALLERS

Despite the aggressive music and graphic lyrical content, death metal does not inspire violence, researchers at Macquarie University have found. They say most death metal fans feel joyful when listening to favourite jams.

Good month

Bad month

LOVERS OF OLIVE OIL

Mamma mia! Extreme cold snaps due to climate change have led to a 57 per cent plunge in Italy's olive oil harvest, making it the worst in 25 years, a study by the Euro-Mediterranean Centre for Climate Change has found.

WEEKEND LIE-INS

If you think that catching up on shuteye over the weekend can make up for missing out on sleep during the week, think again. A team at the University of Colorado, Boulder found it may actually make matters worse, as the changing routine can increase the risk of obesity and diabetes.



'SOUR GENE' DISCOVERED IN LEMONS

Researchers have pinpointed the genes responsible for the sour taste of citrus fruits. The researchers, from the University of Amsterdam and the University of California, Riverside, discovered two genes, CitPH1 and CitPH5, that are more strongly activated in sour citrus fruits than sweeter ones. According to the team, the findings could help to create new, better varieties of citrus fruits.



LINGUISTICS

Chimps' language resembles ours

The sign language used by wild chimpanzees follows the same basic rules as human language

Chimpanzees' gestures exhibit two of the same underlying mathematical patterns found in human languages, researchers at the University of Roehampton have found.

Gestures are likely to be a step in the evolution of spoken language, the researchers say.

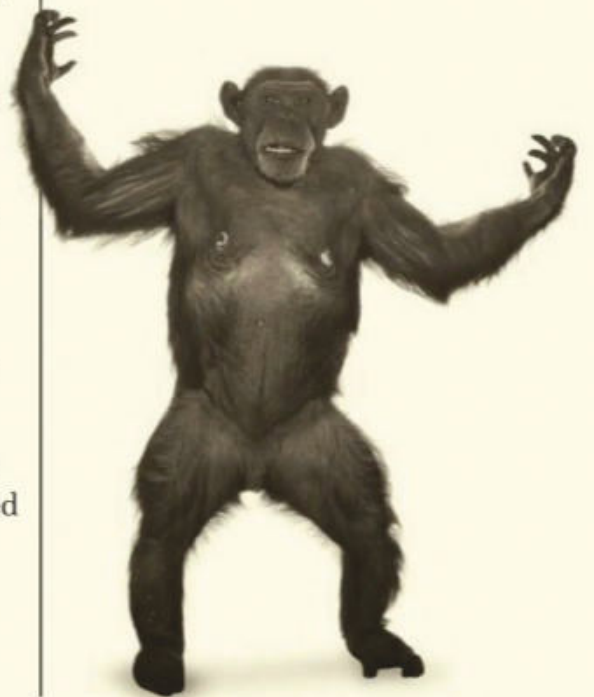
The team studied 81 chimps at the Budongo Forest Reserve in Uganda and recorded over 2,000 of their gestures. The chimps' use of those gestures obeyed two linguistic rules: Zipf's law of abbreviation and Menzerath's law.

Zipf's law says that the more frequently we use a word, the shorter it tends to be. For example, the three most commonly used words in English are 'the', 'be' and 'to'. The chimps most frequently used the gestures of the shortest duration.

Menzerath's law states that the longer a sequence is, the shorter its constituent parts will be. For us, this means that the more clauses in a sentence, the fewer words tend to make up each clause. The equivalent for chimps is that longer sequences of gestures tend to be made up of shorter gestures.

"Primate gestural communication is very different to human language. But our results show that these two systems are underpinned by the same mathematical principles," said researcher Raphaella Heesen. "We hope that our work will pave the way for similar studies, to see how widespread these laws might be across the animal kingdom."

BELOW:
Chimps' gestures share basic principles with human speech





ASTROBIOLOGY

Smaller, cooler stars hold bigger hopes for finding life

A category of small, orange stars may be the best place to look for extra-terrestrial life. So called K-type stars, which are smaller and cooler than the Sun, could provide the perfect conditions for life on exoplanets, according to a new study by NASA space scientist Dr Giada Arney.

Since K-type stars are relatively cool, they burn through their fuel slowly and survive for a long time. While hotter stars like our Sun (a G2V-type, yellow dwarf star) will only survive for 10 billion years, K-type stars can shine for 15 to 70 billion years. During this time, they exhibit very little extreme activity that could disrupt evolving life.

M-type stars, or red dwarfs, are a common target in the search for habitable exoplanets. But these stars go through a violent phase in their youth that can be inhospitable to life. They emit stellar flares, which can boil away water on nearby planets.

K-type stars produce few stellar flares and their temperature stays steady throughout their lifetime. “I like to think that K stars are in a ‘sweet spot’ between Sun-analog stars and M stars,” said Arney.

Arney suggests that exoplanets around K-type stars could be the best place to look for signs of life, or biosignatures. High levels of methane and oxygen in an atmosphere are considered a biosignature, as oxygen and methane naturally react and destroy each other. If an atmosphere has high levels of the gases, there must something producing them.

But exoplanets are so far away from Earth that biosignatures must be strong to be detected. The energetic oxygen gases needed to destroy methane are produced by ultraviolet light. “When you put the planet around a K star, the oxygen does not destroy the methane as rapidly, so more of it can build up in the atmosphere,” said Arney.

ABOVE: The planets orbiting Kepler-62, a K-type dwarf star 1,200 light-years from Earth, may be candidates to support life

RIGHT: An artist's impression of the exoplanet Kepler-62f (left), which is larger than Earth (right) and orbits Kepler-62

STAR CLASSIFICATION FINDING SIGNS OF LIFE

Stars are generally classified using the Harvard Spectral Classification system, based on their effective temperature and colour. The system was devised by Annie Jump Cannon in collaboration with Edward Pickering in 1901.





Prof Jeff Johnson anthropologist

Horizons

Comedians may hold the key to getting humans safely to Mars

PSYCHOLOGICAL STRESS IS LIKELY TO SURFACE DURING A HUMAN MISSION TO MARS. PROF JEFF JOHNSON THINKS AN ON-BOARD 'COURT JESTER' COULD KEEP SPIRITS UP DURING THE LONG AND ARDUOUS JOURNEY. HE IS DRAWING ON HIS RESEARCH ON THE DIFFERING TEAM-BUILDING APPROACHES OF RIVAL POLAR EXPLORERS ROALD AMUNDSEN AND ROBERT FALCON SCOTT TO MAKE HIS CASE

AMUNDSEN'S TEAM MADE IT TO THE SOUTH POLE AND BACK WHILE SCOTT'S PERISHED ON THE RETURN JOURNEY. HOW DID THEIR APPROACHES TO GROUP DYNAMICS DIFFER?

Well, Roald Amundsen actually put people through tests before they set off to make sure that they would take orders and, in particular, whether they

would challenge any of them. Amundsen would set up situations where there would be an ambiguous context to see what their responses would be, and if somebody questioned him, they were eliminated. But there was also Adolf Lindstrøm, the cook; he was a key figure. If you read Amundsen's diary, he writes that Lindstrøm was basically the most important person on the expedition.

WHY WAS THAT?

Lindstrøm was the comedian. He didn't actually go to the South Pole, but you've got to remember that the walking expedition was a small component of the overall time that they were on the ice. They were there for well over a year, waiting to walk to the Pole. They had to wait during the winter and it's a very tense time when people are idle, without a lot to do. Lindstrøm played an essential role in keeping the peace in the group when there were tense moments.

WHAT MAKES PEOPLE LIKE LINDSTRØM DIFFERENT FROM THE REST OF US?

People like Lindstrøm have a high social intelligence. It's hard to know exactly what went on – diaries are not necessarily a good indication because people may want to portray a different version of events – but I do know that during tense moments, Lindstrøm would do something funny to get everybody to laugh, which would break the tension.

HAVE YOU SEEN THIS SORT OF THING IN ACTION IN YOUR OWN RESEARCH?

I did participant observation as an anthropologist while I spent two years working as a carpenter in a salmon fish camp in Bristol Bay, Alaska. That was the only way to do the research – I had to live there and be a part of it. I observed the emergence of a 'court jester' during a strike that the fishermen held. There was lots of tension because people were losing money during the strike, but they used to make fun of this one individual and he played along with it – he became the butt of their jokes. He was the worst fisherman

WIKIPEDIA COMMONS



Joker in the pack: Adolf Lindstrøm (first from right) played a crucial role in Roald Amundsen's (with the pipe) 1911 expedition to the South Pole



“Lindstrøm played an essential role in keeping the peace in the group when there were tense moments”



in the camp, even though he was a captain. But he was well-loved. The other fishermen held a mock-funeral for him, they buried him in the tundra, they'd pile up benches in front of his door so he couldn't get out... After the strike was over, he received over-limit fish-transfers. If you went over your 12,000lb limit in 24 hours, you could give away your extra fish to anybody who hadn't reached their limit. The other fishermen gave their extra fish to this court jester, so he was rewarded for his role.

IF WE'RE TRYING TO SELECT THIS TYPE OF PERSON FOR A MISSION TO MARS, WHAT SORT OF QUALITIES WOULD WE BE LOOKING FOR?

There are individuals who have these certain innate abilities that you want to be able to recognise and include when you're putting together groups that are going to be isolated, such as those going into space. There's a number of different

roles that we've discovered are important, but one of them is somebody who has humour. That's clearly important.

So, you'd want to have somebody like Lindstrøm, somebody who is not only good at what they have to do (he was a very good cook) but who also has another skillset over and above what's in the job description. You would want the same thing to be true for any kind of expedition to space. It could be comedians, it could be story-tellers, it could be peace-makers... It has to do with the emergent properties of groups. We can put people together thinking that they're going to work together in a certain way, but over the course of time we get these emergent properties, particularly with these informal roles, that are difficult to predict, particularly when there's a crisis. But I think we can do a better job of putting people together that will do better over the long run. Some of these things are latent in the sense that they

don't come out and surface until they're needed. That's what happened in my research with the fishermen when the strike happened. The comedian role emerged and it went away when the strike was over. These are the kinds of things that make groups more adaptable and help them function better, and I don't think enough attention has been paid to them.

You can think about it in terms of atoms: when you put different elements together, they produce different kinds of things. It's the same with people. They may have their own characteristics, but when you put them together, they're going to create a different kind of situation and we want to have a better idea of what that might be.

PROF JEFF JOHNSON

Jeff is a professor of anthropology at the University of Florida. Interviewed by BBC Science Focus commissioning editor Jason Goodyer.



Wyoming, USA

PALAEONTOLOGY

Fossil of first known perching bird found

Specimen holds clues to the origin of more than half of current bird species

The fossilised remains of what could be the earliest example of a passerine bird have been unearthed in Wyoming, USA, according to a paper published in *Current Biology*. The remains are believed to date back to the early Eocene, 52 million years ago.

Passerine birds are those that have feet adapted for perching and account for approximately 6,500 of the 10,000 bird species alive today. But scientists are unsure of their origins. “It’s fascinating because passerines today make up most of all bird species, but they were extremely rare back then,” said Dr Lance Grande, an author of the paper. “This particular piece is exquisite; it’s a complete skeleton with the feathers still attached, which is extremely rare in the fossil record of birds.”

Eofringillirostrum boudreauxi, as the bird has been dubbed, is the earliest example of a bird with a finch-like beak. “These bills are particularly well-suited for consuming small, hard seeds,” said Dr Daniel Ksepka, the paper’s lead author. “The earliest birds probably ate insects and fish, some may have been eating small lizards,” he added. “Until this discovery, we did not know much about the ecology of early passerines. *E. boudreauxi* gives us an important look at this.”

The paper also describes a second passerine fossil, christened *E. parvulum*, from 47 million years ago. *E. parvulum* was found in Germany and is shedding further light on the origins of passerines. “We were able to show that a comparable diversity of bill types already developed in the Eocene in very early ancestors of passerines,” said co-author Dr Gerald Mayr of the Senckenberg Research Institute in Frankfurt. “[Also] the great distance between the two fossil sites implies that these birds were widespread during the Eocene, while the scarcity of known fossils suggests a rather low number of individuals.”

LANCE GRANDE/FIELD MUSEUM X3



- 1. Scientists at the Fossil Lake dig site in Wyoming search for more preserved examples of early life in the rock
- 2. Researchers inspect the extracted rock containing the fossil of the earliest known example of a perching, seed-eating bird, dubbed *Eofringillirostrum boudreauxi*
- 3. *E. boudreauxi* has been spectacularly preserved in rock. You can clearly see its feathers and finch-like beak



3

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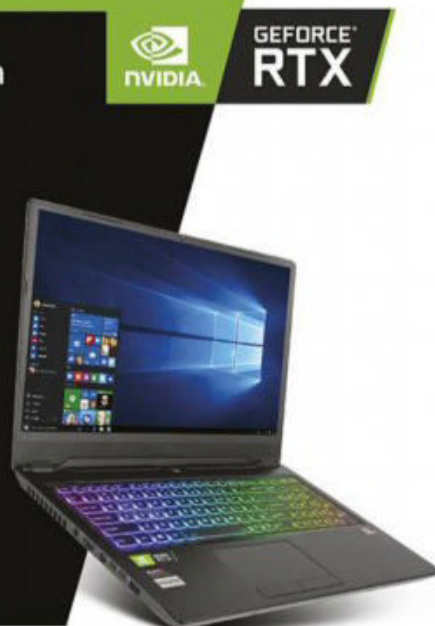
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1 REVIEW

FEBRUARY
HEATWAVE:
ARE UK CLIMATE
PATTERNS
CHANGING?

February's sudden warm weather broke records, but whether it was climate change isn't an easy question.

The UK was treated to a burst of early spring in February, breaking the record for the warmest ever February day, two days running. Temperatures passed 20°C in Wales and the London area, in stark contrast to the plunging temperatures and deep snow brought by the Beast from the East at the same time last year.

Is this the inevitable result of climate change? And what are the effects of warm weather so early in the year?

Is it down to climate change?

It's important not to confuse weather with climate: we can't judge the climate on the



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events of a few days. “Weather is what we experience on a day-to-day timescale, and climate is what we experience over a much longer timescale,” says Dr Dann Mitchell, climate scientist at the University of Bristol.

What’s more, unusual weather events in isolation are difficult to pin on climate change. Mitchell suggests that there are three main factors that brought the February heatwave: the dry weather for much of early 2019 making it easier for the Sun to heat dry soils; high pressure air over the UK and Europe drawing in warm air from equatorial regions such as the Canary Islands; and the atmosphere absorbing more energy because of the increased carbon dioxide that we’re putting into it. “The absorption of energy by carbon dioxide is a very strong contributor, which is why I think climate change is making these sorts of events more frequent,” he says.

Such warm weather so early in the year, while still unusual, is becoming much more likely. “In our non-altered climate state, it was probably closer to [once in] 10,000 years. In that sense, climate change has probably increased the frequency so that it’s gone from a one-in-10,000-year event to a one-in-100-year event,” Mitchell says.

Are there immediate effects of the warm weather?

In the immediate aftermath of the heat came fires. Ashdown Forest in East Sussex, Marsden moorland in West Yorkshire, and Arthur’s Seat in Edinburgh all suffered from outbreaks of fire. Early 2019 saw less rain than usual and, according to firefighters tackling these blazes, the addition of the warm spell dried out the soil enough to make fires of this sort more likely.

The early emergence of warm, sunny weather proves perilous to wildlife, especially when it doesn’t stay. Many types of species take cues from the weather

1. Picnickers got the chance to enjoy warm sunshine this February

2. The same time last year was a chillier affair, with deep snow drifts and bitterly cold conditions



around springtime: insects and mammals come out of hibernation, flowers bloom, some birds start to nest, and others even return from migration. According to the Portland Bird Observatory, swallows and house martins were both spotted in the UK in mid-February, despite usually returning from Africa around April.

Cold weather following an early warm spell has a knock-on effect on the availability of food. A substantial drop in temperature leaves insects and flowering plants struggling. Hedgehogs, awoken from their hibernation, and early broods of baby birds, often can’t find sufficient food to make it through until spring.

What can I do to help wildlife?

The RSPB has published advice on how to help wildlife which could suffer the consequences of a cold snap. First of all, you can provide a food source, such as mealworms and fat balls, and fresh water. You could also consider putting a bird house in your garden, or even planting pollen-rich plants as a source of nectar for insects.

by **SARA RIGBY**

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

DISCOVER MORE



Visit the BBC’s Reality Check website at bit.ly/reality_check_ or follow them on Twitter @BBCRealityCheck

Is this weather so unusual?

The warmth was odd, both here and across western Europe and Scandinavia, according to Dr Dann Mitchell, climate scientist at the University of Bristol. “Records have been broken everywhere, and we’re in a part of the world where we have very long temperature records,” he explains. “We can look back to, say, 1880 or even 1850 in some cases, so we really can tell that this is a very extreme February temperature.”

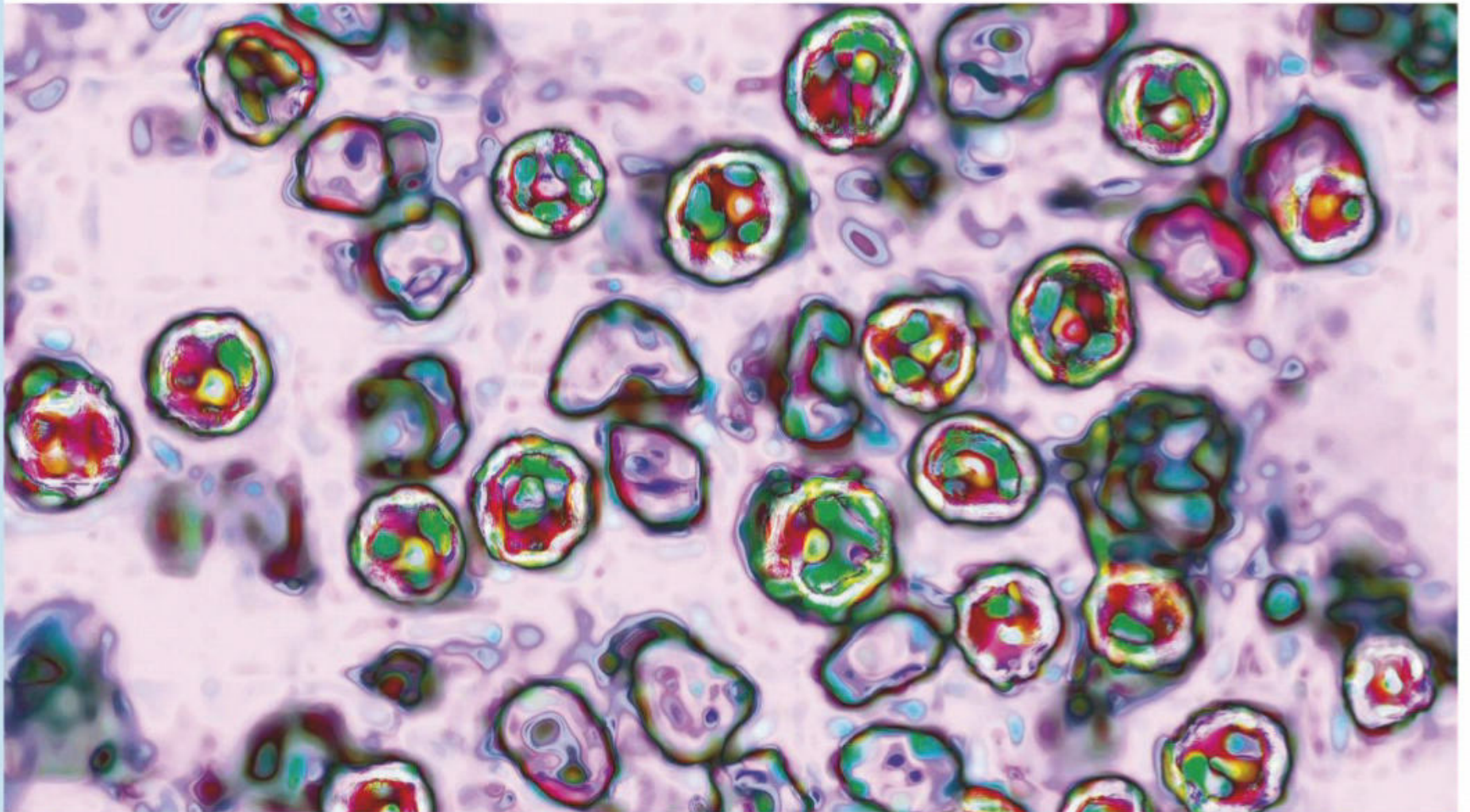


2

ANALYSIS

MEASLES: SHOULD I WORRY THAT OTHER PEOPLE AREN'T GETTING VACCINATED?

The number of people getting the MMR vaccine is falling, which could have consequences for 'herd immunity'



The measles virus, as viewed down a microscope

Back in 2017, the UK eliminated measles for the first time: the number of cases was so low that the disease could no longer spread throughout the general population.

Though it may have sounded like the war against measles was won, the disease is only kept at bay through continual vaccination, since the virus isn't yet completely eradicated. The World Health Organization therefore recommends that at least

95 per cent of all children receive two doses of the vaccine by the age of five. According to the Centers for Disease Control and Prevention in the US, a single dose of the MMR vaccine is 93 per cent effective at preventing measles, whereas a second dose brings this up to 97 per cent.

In 2018 there were more than three times as many confirmed cases of measles in England than the year before. Dr Seth Berkley, CEO of Gavi, the Vaccine Alliance, an

international organisation investing in vaccination, blamed Europe's general decrease in vaccination on "complacency about the disease and the spread of falsehoods about the vaccine". This is something that *Science Focus* noticed first-hand. When we researched the laws regarding vaccinations, our internet search brought up a series of websites advocating anti-vaccination ideology.

Prof Matt Keeling, who studies epidemiology at the University

of Warwick, explains that the recommended 95 per cent level is to achieve 'herd immunity'. "Measles is highly transmissible," he says. "Before vaccination, each infected child was estimated to spread infection to 15 to 20 others on average. If we vaccinate 95 per cent of the population, then 19 out

dropped by about half a per cent per year for the past four years.

"While a 0.5 per cent change sounds small, the issue is that we are not vaccinating enough children to prevent future outbreaks," says Keeling. "With just 88 per cent vaccination, we are building up pools of susceptible children, who



"I am deeply concerned that when the vaccine has been proved by multiple independent groups to be safe, there are still families that refuse to protect their children, and therefore also endanger others who may not be fully protected"

of these 20 secondary cases are protected, and the disease will die out and cannot re-invade."

Limiting the disease's spread means that the immune herd protects people who can't be vaccinated, such as children who are too young or have medical complications, or people who have a severely compromised immune system that can cause them to lose their vaccine immunity.

SERIOUS DISEASE

"In general, the fewer individuals vaccinated, the more cases we are likely to see in the future. Given the severe effects of measles – brain damage or even death – we need to do all we can to reduce cases. It's estimated that measles is fatal in 1 in 25,000 cases, and can cause serious problems to the unborn child if a mother gets infected during pregnancy," says Keeling. "The other issue is that if the vaccination level is low and we don't see many cases of measles, then we are storing up lots of susceptible individuals, which could give rise to large-scale epidemics."

In 2018, approximately 88 per cent of children in the UK had received two doses of the MMR vaccine by the age of five, a figure which has

may be aggregated in certain schools or areas. This means that we would expect to start seeing localised outbreaks, like the epidemic that was seen in Swansea in 2013, where there were several complications and one death."

The outbreak in Swansea came 10 years after widespread, unfounded fears about the vaccine's safety had led to MMR uptake dropping to only 67.5 per cent among two-year-olds in the area. The result was a large group of susceptible 10- to 18-year-olds, who were the main contributors to the 1,200 confirmed cases.

"I am deeply concerned that when the vaccine has been proved by multiple independent groups to be safe, there are still families that refuse to protect their children, and therefore also endanger others who may not be fully protected," says Keeling.

The MMR vaccine is available on the NHS at any age. If you aren't sure whether you've received the full course, check with your GP.

by **SARA RIGBY**

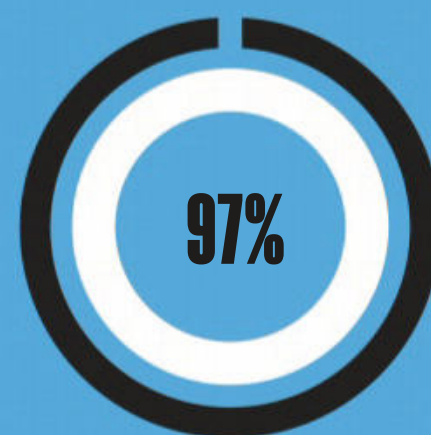
Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

NEED TO KNOW

The data behind the measles vaccination

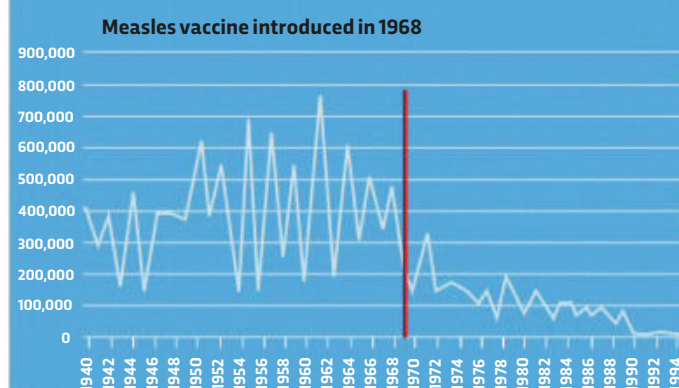
VACCINATE

A course of two doses of MMR vaccine is 97 per cent effective against measles



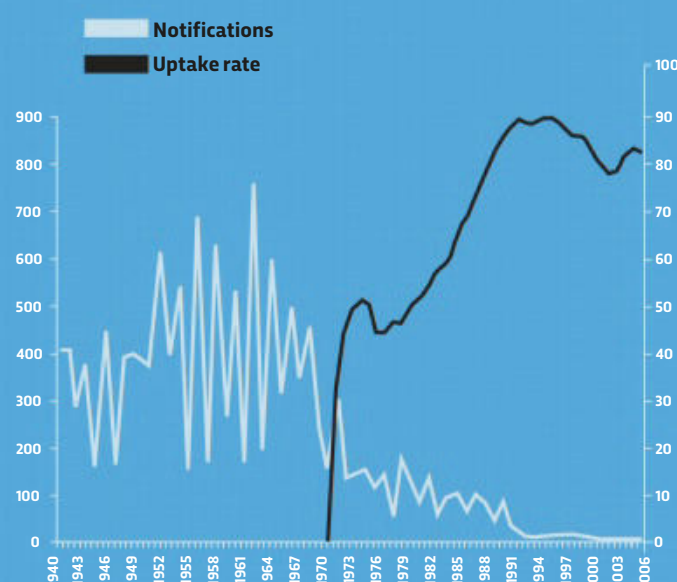
Measles through the ages

Annual number of measles cases in England and Wales from 1940 to 1995



VACCINATION = FEWER MEASLES CASES

Measles notifications (left axis) and vaccination uptake percentage (right axis), 1940-2007



3 COMMENT

CASTER SEMENYA: DOES HIGH TESTOSTERONE GIVE HER AN ADVANTAGE?

The Olympic gold medallist Caster Semenya's naturally high testosterone levels are said to boost her sporting prowess, but is this really the case?

Caster Semenya, the South African athlete and Olympic gold medallist, has been embroiled in controversy for much of her career over her higher than usual testosterone level, a disorder of sex development (DSD) known as hyperandrogenism.

Semenya has recently been at the Court of Arbitration for Sport (CAS) in Lausanne, appealing the new rule proposed by the

Caster Semenya of South Africa after winning the women's 800m at 2017's IAAF World Athletics Championship in London



International Association of Athletics Federations (IAAF), the governing body for athletics, that prevents female athletes with hyperandrogenism from competing in events from 400 metres to 1 mile if their testosterone level is above five nanomoles per litre. For comparison, South Tees Hospitals NHS Foundation Trust gives reference ranges for testosterone levels of 0.7 to 2.8 nanomoles per litre in women, and 10 to 30 nanomoles per litre in men.

We do not know the details of Caster's medical record other than that she was born and raised as a female baby, infant and girl and went on to become a talented athlete.

As a result of blood tests, she was found to have a testosterone level that was above what's usually seen in women. The IAAF (incorrectly) attributes her athletic success to the effects of the high testosterone and requires her to lower it, through pharmacological or surgical means, to be eligible to compete in these events. This rule is based on a 2017 IAAF-funded study which claimed to find an athletic advantage based solely on testosterone levels. Other studies have criticised this conclusion.

It seems likely that Semenya has Androgen Insensitivity Syndrome (AIS). A developing foetus with AIS, although being genetically male with XY chromosomes and internal testes, does not respond to testosterone because of a defect in the testosterone receptor gene. As a result, the infant is female at birth and develops as a normal girl and then woman. The diagnosis is often not made until the (adult) woman fails to menstruate or proves infertile and then seeks medical advice. Many have had their testes removed.

In Semenya's case, the diagnosis was likely made after a routine anti-doping test found her high testosterone level. Whatever the exact genetic cause, she is severely insensitive to testosterone.

This is the crux of the argument and one that the IAAF chooses to avoid. Women with AIS cannot respond to injected testosterone, so it would be no use to them as a doping agent. Prof Malcolm Ferguson-Smith, of the Cambridge Resource Centre for Comparative Genomics, tested 3,387 women athletes at the Atlanta Olympic Games and found eight with XY sex chromosomes, of whom seven had AIS. Their heights were in the normal

male range. Six of them had already had a their testes removed and were still able to reach Olympic standard. In other words, a virtually complete lack of testosterone did not appear to affect their athletic performance.

In a subsequent paper, Ferguson-Smith explained the high number of XY women with AIS and other DSDs in elite sport. Rather than testosterone levels, it's likely due to genes on the Y chromosome, especially those associated with height in the male range.

All athletes are selected largely on their physical attributes due to their genetic constitution. Favourable genes on many chromosomes are known to be involved and it is discriminatory to exclude those athletes who have favourable genes on the Y chromosome. These athletes with AIS are at no greater advantage than those who are selected because of favourable genes on other chromosomes. As Ferguson-Smith explains, "women with hyperandrogenism possess no physical attribute relevant to athletic performance that is neither attainable, nor present in other women."

Thus, the IAAF is 'barking up the wrong tree' medically (and ethically) by attempting to exclude women with AIS from elite sport. Let's hope the CAS does not fall into the same trap.

by **PROF PETER SONKSEN**,
with help from **PROF MALCOLM
FERGUSON-SMITH**

Prof Peter Sonksen is a retired professor of endocrinology. He has an OBE for his contribution to fighting against doping in sport



“Women with AIS cannot respond to injected testosterone, so it would be no use to them as a doping agent”

FOLLOW THE CONVERSATION



@Karkazis

Katrina Karkazis is an expert on testosterone and tweets about sex and gender.



@DarylAdair

Daryl Adair is associate professor of sport management at the University of Technology Sydney. He is an expert in sports policy.



@MitrP

Payoshni Mitra is a researcher and athletes' rights advocate working on gender issues in sports.



@Madeleine_Pape

Madeleine Pape is a middle-distance runner and Olympian. She's also a PhD candidate in sociology, researching gender.

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MASTERS OF DISASTER

Scientists are recreating extreme weather and natural disasters inside labs around the world. Their aim: to prepare for the next big catastrophes

Words: HAYLEY BENNETT





MAKING WAVES

← FLOWAVE,
EDINBURGH

Capable of making 28m-high waves, Edinburgh University's FloWave is the world's largest circular wave and tidal tank. The 25m-wide, 5m-deep pool was built to test wave and tidal energy machines (which convert the ocean's energy into electricity), as well as for basic research on how waves are made at sea. Using 168 computer-controlled paddles, visible here around the edge, FloWave can produce waves and tidal currents in any direction. Recently, Edinburgh researchers teamed up with Oxford University academics to better understand how 25m-plus 'freak waves' can form when waves travelling in different directions cross paths. These giant waves are thought to have sunk many a ship over the centuries. The plume of water in this photo, however, is a 'party trick', and wouldn't occur naturally. Like a stone's throw in reverse, ripples made at the edge of the tank travel towards the centre, where they converge and shoot two tonnes of water straight up in the air.





DOUGLAS LEVERE/UNIVERSITY AT BUFFALO, MARIA KOLIOU/TEXAS A&M UNIVERSITY, SCANIA



SHAKE IT UP

← E-DEFENSE FACILITY, JAPAN

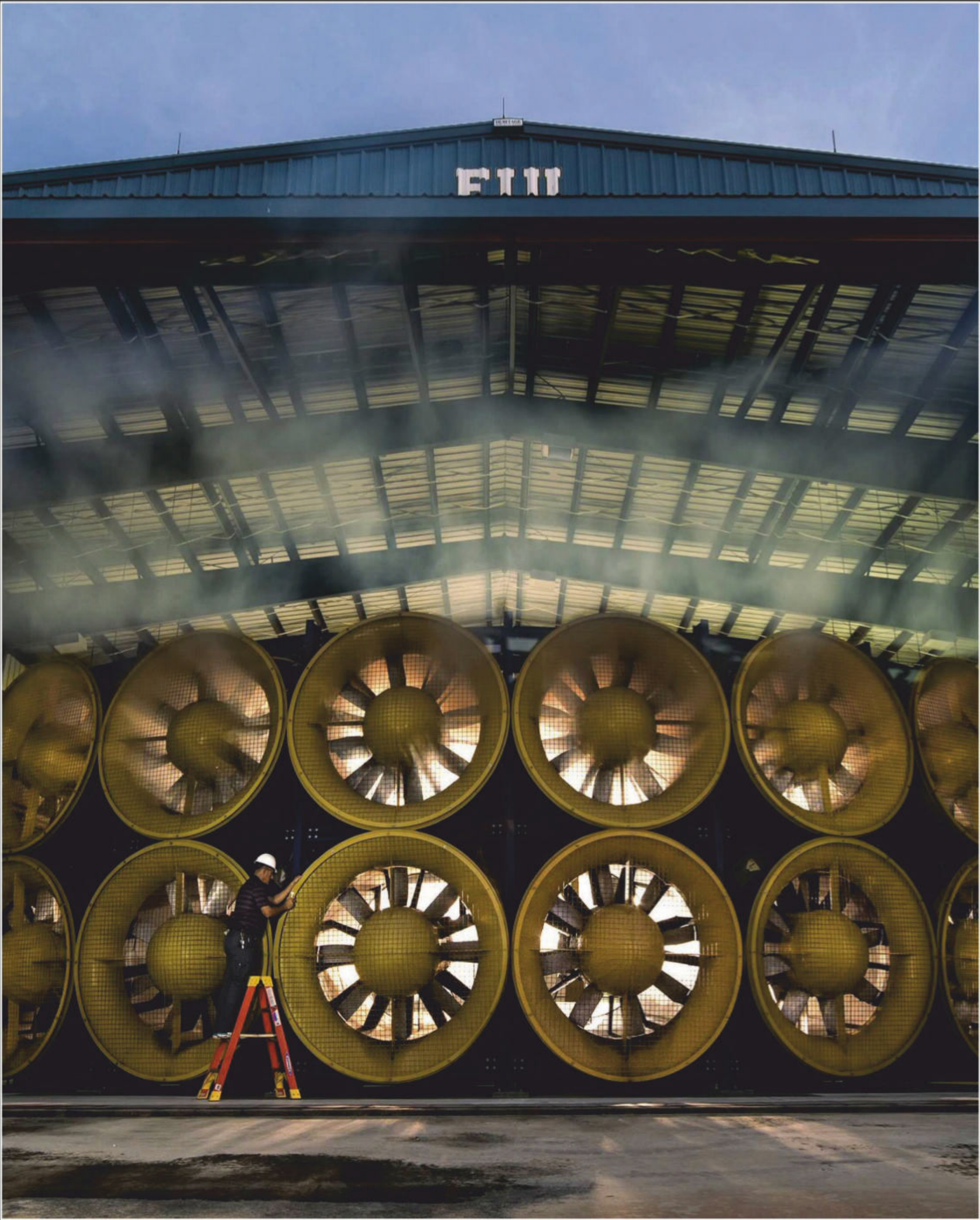
The ‘shake table’ at the E-Defense facility (‘E’ stands for ‘Earth’) near Kobe, Japan, is the largest in the world. The 20m by 15m platform hides an array of 24 pneumatic pistons, which are controlled by engineers to shake full-scale buildings in three directions, at earthquake-level intensities. When Texas A&M University engineer Dr Maria Koliou visited in February 2019, she got to wander around these fully furnished, wood-framed houses and then watched as her Japanese colleagues ran their shake programmes – one of which simulated the 6.9 magnitude Kobe earthquake that destroyed 150,000 buildings in 1995. “It was pretty impressive,” says Koliou. “I hadn’t seen a full-scale test before.” The right-hand building was even grounded in soil with pipes running through it, to get closer to real-life conditions.

The Japanese scientists surveyed the structural damage caused to the houses, with the aim of learning how building companies can better protect people’s homes during earthquakes.

ICE ICE, BABY

↑ SCANIA TEST FACILITY, SWEDEN

At this sophisticated climate facility in Södertälje, Sweden, you can control the weather. Developed by truck manufacturer Scania at a cost of £33m, it took three years to build and is intended for testing heavy vehicles in the harshest weather conditions. The snowdrifts in this picture were produced by snow cannons like those used at ski resorts, while a single 3.75m-high fan provides the wind for snow storms. On another day, conditions could be more akin to a desert heatwave, thanks to a temperature control system that goes as low as -35°C and up to 50°C. The humidity can range between 5 and 95 per cent, and even the droplet size of simulated rain is adjustable. Rollers under the parked vehicles allow the researchers to mimic speeds of up to 100km/h as they study variables such as driver visibility, windscreen wiper function, and the reaction of different components. Scania hopes that its facility will help improve fuel efficiency in demanding conditions, cutting down vehicles’ emissions.



FLORIDA INTERNATIONAL UNIVERSITY, INSURANCE INSTITUTE FOR BUSINESS AND HOME SAFETY

SUCH A BIG FAN

← WALL OF WIND, FLORIDA

Together, the motors behind these massive fans provide the power of more than eight Mercedes Formula 1 racing cars at top speed. They're also capable of simulating hurricane winds strong enough to rival Katrina, the storm that devastated the city of New Orleans in 2005. Researchers at Florida International University use the Wall of Wind facility to test building materials and outdoor structures like solar panels that need to withstand strong winds. The fans are independently controlled and can rotate 1,800 times per minute, generating winds of up to 253km/h (equivalent to the most destructive type of hurricane – 'Category 5'). Test structures are placed on a turntable in front of the fans, before researchers beat a hasty retreat to view the action on-screen from the control area. Among other things, experiments have tested scaled-down bridge sections (to help with the hurricane-proofing of bridges), and the wind required to lift metal roofs off buildings.

BURNING UP

↓ WILDFIRE SIMULATOR, SOUTH CAROLINA

Wildfire spreads like... well, wildfire, in this specially designed wind tunnel in Chester County, South Carolina. This is part of a six-storey research facility belonging to the Insurance Institute for Business and Home Safety (IBHS). The tunnel is used to simulate what happens when burning embers are driven by wind to produce the 'ember storms' often seen in wildfires, which can be devastating to nearby buildings. On the right of the picture, embers – made in chambers filled with mulch and wood – are blown across the test space from metal ducts. The building sits on a rotating platform so that the embers can be blown from different directions. Researchers examine how the embers get into buildings through vents, and look at how decking and debris can help wildfires to spread. In this picture, plants below the front windows are acting as kindling, while the wooden step outside the front door is also adding fuel to the flames.



© Insurance



SHIVER ME TIMBERS

← DEBRIS IMPACT FACILITY, TEXAS

You can't shoot a bullet through a brick wall, but fire a piece of wood at it hard enough and you might have more luck. In the image to the left, the strip of wood shatters, but it isn't quite moving fast enough to break through the bricks. However, at 160km/h, it rips right through, as researchers at the Debris Impact Facility at Texas Tech University have demonstrated by firing a piece of wood from their pneumatic cannon. Even though a bullet shot from a gun moves faster, a strip of wood is heavier, so the impact is greater. This explains why debris thrown at high speed by a tornado can cause so much damage. The researchers use their cannon to simulate the impacts of flying debris in tornadoes travelling at up to 400km/h, testing storm shelters, safe rooms, doors and windows to their limits.



RECIPE FOR DISASTER

← UNIVERSITY OF BUFFALO, NEW YORK

How do you cook up volcanic lava in the lab? A team at the University of Buffalo in New York has the recipe down: take 45 litres of basaltic rock, put it in a furnace, bake for four hours until it reaches 1,316°C, then pour it into an insulated steel box. In this photo, volcanologist Dr Ingo Sonder stirs the lava. His experiments examine "the basic physics of what happens when water gets trapped inside molten rock". This could help scientists learn more about explosions like the one that triggered the Icelandic ash cloud event in 2010, when meltwater from a glacier flowed into the erupting Eyjafjallajökull volcano and threw ash 9km into the air, leading to the cancellation of nearly all European flights for five days. By injecting water into DIY lava, Sonder's team has discovered that spontaneous explosions are more likely to occur when water meets lava at a depth below the surface exceeding 30cm. At shallower depths, the water can escape as steam before it causes an explosion. **SF**

by HAYLEY BENNETT (@gingerbreadlady)

Hayley is a Bristol based science writer and editor. She is the co-author of *The Big Questions In Science* (£5.99, Andre Deutsch).



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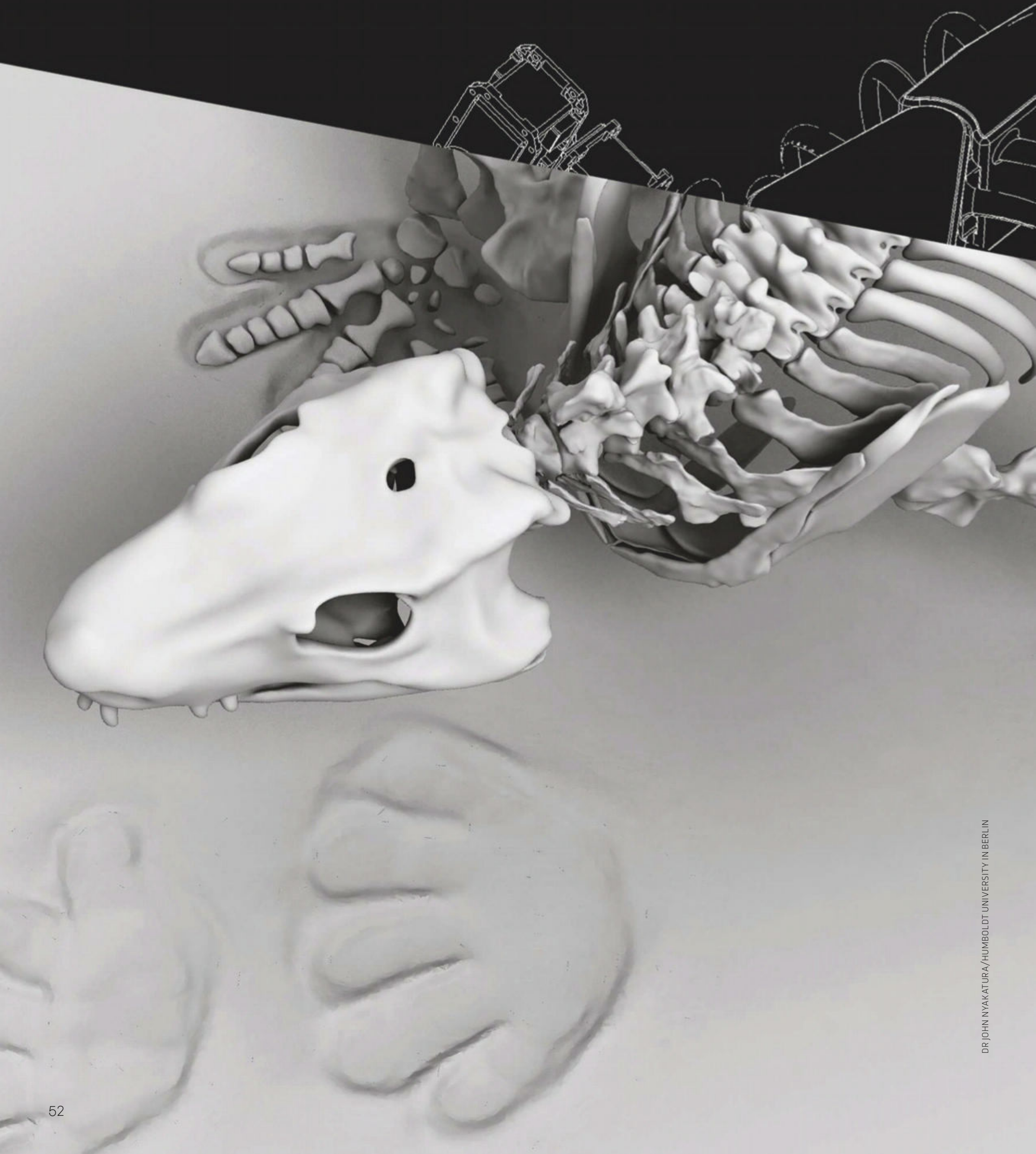
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THE WALK OF PREHISTORIC LIFE

MEET THE SCIENTISTS USING
COMPUTER SIMULATIONS AND
ROBOTICS TO RECREATE THE
MOVEMENT OF A CREATURE THAT
LIVED BEFORE THE DINOSAURS

by **DARREN NAISH**

S ometime around 400 million years ago, the land-living, four-legged vertebrate animals properly called tetrapods evolved from their aquatic fish ancestors. Early, land-going tetrapods – animals like the famous *Ichthyostega*, a short-snouted aquatic animal discovered as fossils in 360-million-year-old rocks in eastern Greenland – were seemingly slow, clumsy walkers that kept their bodies close to the ground and appeared to lack agility or speed when moving on land. Any analysis of the fossils points to them having a very inefficient gait. But if we look at the enormous variety of land-living tetrapods that evolved later during Earth's history, including those that live alongside us today, it's obvious that far greater agility, speed and efficiency eventually evolved.

Supposedly, it was only when more modern tetrapods evolved, such as reptiles and the ancestors of mammals – a tetrapod group known collectively as amniotes, did things change. These new animals gradually evolved energy-saving poses and an ability to hold their bodies up above the ground. ●

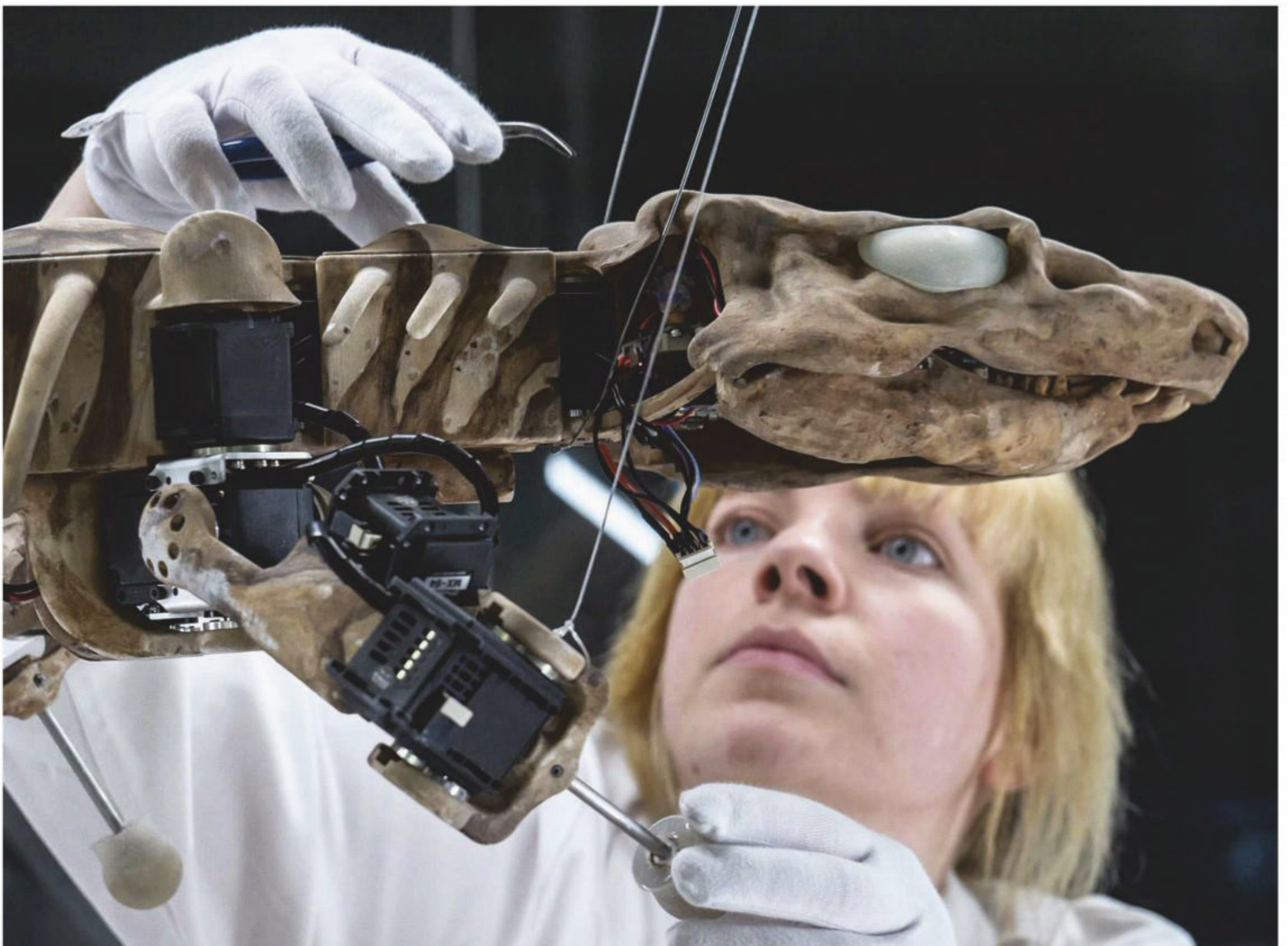
“*OROBATES* CAN BE REGARDED AS A KEY FOSSIL DUE TO ITS PLACEMENT WITHIN THE TREE OF LIFE”

BELOW Stefanie Griebisch prepares a modified OroBOT for a demonstration of its walking ability

● But when did the key components of ‘advanced tetrapod’ gait appear? And what were the key events that gave later tetrapods their ability to scurry about quickly and efficiently, while holding their bodies higher up off the ground?

One team is turning to sophisticated computer modelling and robotics to find out. Led by Prof John Nyakatura of the Humboldt University of Berlin, the researchers are focussing on *Orobates*, an early tetrapod known to have lived in the region that later became Germany around 260 million years ago and traditionally considered to be close to the ancestry of amniotes. This probable evolutionary position is significant, since it means that *Orobates* might serve as proxy for the amniote ancestor. In other words, if we learn more about the biology and behaviour of *Orobates*, we might understand more about amniotes as a whole.

But why choose *Orobates* specifically as a focus of research, and not another diadectid (the tetrapod group to which *Orobates* belongs) or early tetrapod?



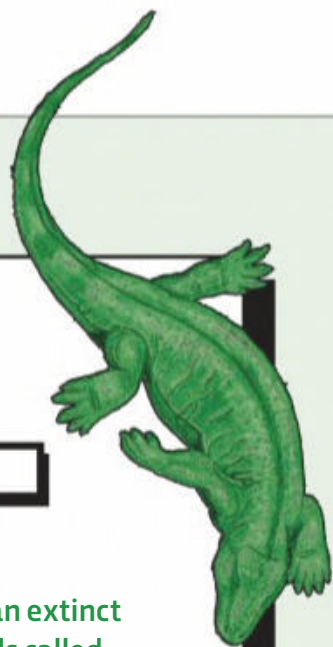
WHAT WAS OROBATES?

Darren Naish

Orobates is a member of an extinct group of ancient tetrapods called diadectids and lived around 260 million years ago during what's known as the Middle Permian period.

Diadectids were superficially lizard-shaped, chunky and had a robustly constructed skull adapted for the consumption of tough plant material. They might have eaten small animals too. They were – so far as we know – the very first group of tetrapods to become specialised herbivores and their bulky, barrel-shaped bodies contained the large guts needed for the digestion of plant material. Diadectids were also the first tetrapod group to evolve large size, the biggest reaching three metres and perhaps 150kg. This makes it a giant compared to the majority of other ancient land-living tetrapods. *Orobates* was not quite so big, at 85cm and 4kg. *Orobates* is a relatively new addition to the diadectid group and was scientifically named and described in 2004. It was discovered in the Bromacker sandstone quarry in the Thuringian Forest of central Germany, a locality famous for its many well-preserved Permian fossils.

When *Orobates* was alive, Germany was landlocked and part of the gigantic supercontinent Pangaea. Conditions across Pangaea were hot and mostly dry, and land-living animals were adapted to cope with the conditions. Many were capable of building burrows where they took refuge during the day, and this was likely the case for *Orobates*. It appears to have been a good walker and mostly an animal of upland environments, rather than swamps or valleys.



First, it is known from excellently preserved, complete remains. Enough is known about the skeleton of *Orobates* to accurately reconstruct the way its bones fitted together when it was alive, and hence make inferences about its posture and locomotion.

Second, a set of fossilised tracks found in 2007 in the same region as the *Orobates* skeletal remains, is of exactly the right age in geological terms, and was made by an animal that matches *Orobates* in size and shape. It was almost definitely made by *Orobates* itself, which is rare in palaeontology and important since it means we have a direct record of how this animal placed its feet while walking.

Third, *Orobates* is from an especially interesting part of the tetrapod family tree. “It can be regarded as a key fossil due to its placement within the tree of life, very close to the origin of the amniotes – a group that largely became independent from water,” says Nyakatura.

DO THE LOCOMOTION

Orobates was not much like modern amphibians, but nor was it a reptile or a relative of mammals. “It was a medium-sized creature, about 85cm long, that was a melange of what could loosely be called amphibian-like and reptile-like features. A salamander-y, lizard-y thing,” says team member Prof John Hutchinson of the Royal Veterinary College in Hertfordshire, UK.

Nyakatura and his colleagues therefore embarked on an ambitious project. Building on previous work that looked at the locomotion of salamanders, crocodilians and other tetrapods, and combining the track evidence with data gleaned from the *Orobates* skeleton, they wanted to use computer modelling and real-world robotics to analyse the gait and posture of *Orobates*. Digital and real-world robotic skeletons could be custom built to fit the track and show how the animal placed its feet. But what sort of gait would be required in order to do this precisely? Their aim was to reverse-engineer the possibilities that might be available to this animal.

The robot constructed for this study is perhaps the most intriguing component of the work, and certainly the part that has received the most attention from the media. Dubbed OroBOT, it has a range of movements in its limbs and body designed to mimic that of the real *Orobates*, numerous mobile joints like those present in a real animal, and flexible feet that allow it to properly contact the ground with each step. It is carefully designed so that its mass distribution matches that of a live *Orobates*, and it can employ numerous subtle variations in gait and pose.

In action, OroBOT has a surprisingly realistic air, moving and flexing with a real-world feel and recalling the walking style of a big lizard or small crocodilian. “It was a magical moment for us when the robot first walked,” says Nyakatura. “The motor went through some tests and the robot did something that resembled push-ups. Then it started to walk for the first time. I probably will not forget this moment. We enjoyed it a lot.”

Walking with dinosaurs

Words by **DARREN NAISH**
Infographic by **JAMES ROUND**

Dinosaurs dominated life on land for more than 160 million years, and the many skeletal remains they left behind are among the most familiar of fossils. But dinosaurs did not leave us with bones alone. Millions of tracks, made by the forefeet and hindfeet of species belonging to all the major dinosaurian groups, are known from rocks worldwide.

Fossilised dinosaur tracks have been known to science since the 1850s. By matching toe number and shape, foot proportions, claw shape and track size with skeletal remains, experts have been able to identify tracks to specific dinosaur groups, and sometimes to species. The smallest tracks, made by chicken-sized dinosaurs, are

a few centimetres long while the biggest – made by long-necked, herbivorous sauropods – are a gargantuan 1.8m in length. Sequences of tracks – termed trackways – are sometimes many metres long, the longest being over 150 metres.

The tracks are not rare or hard to find, but are abundant and well-preserved at numerous locations. Rich track-bearing sites exist in England, Scotland, China, Brazil, the USA and Australia. Studying the tracks can show what sort of environments dinosaurs preferred, how they moved and how quickly, and provide information on the soft tissue anatomy and skin texture of their feet.

To read the infographic, begin at at the top and follow the lines down to explore footprint shape and size, and geological period.

◆

Theropods
Flesh-eating dinosaurs

Dinosaur track visuals

◆

Thyreophorans
Armoured dinosaurs

 Lighter colour denotes forefoot

◆

Marginocephalians
Horned and bone-headed dinosaurs

 Darker colour denotes hindfoot

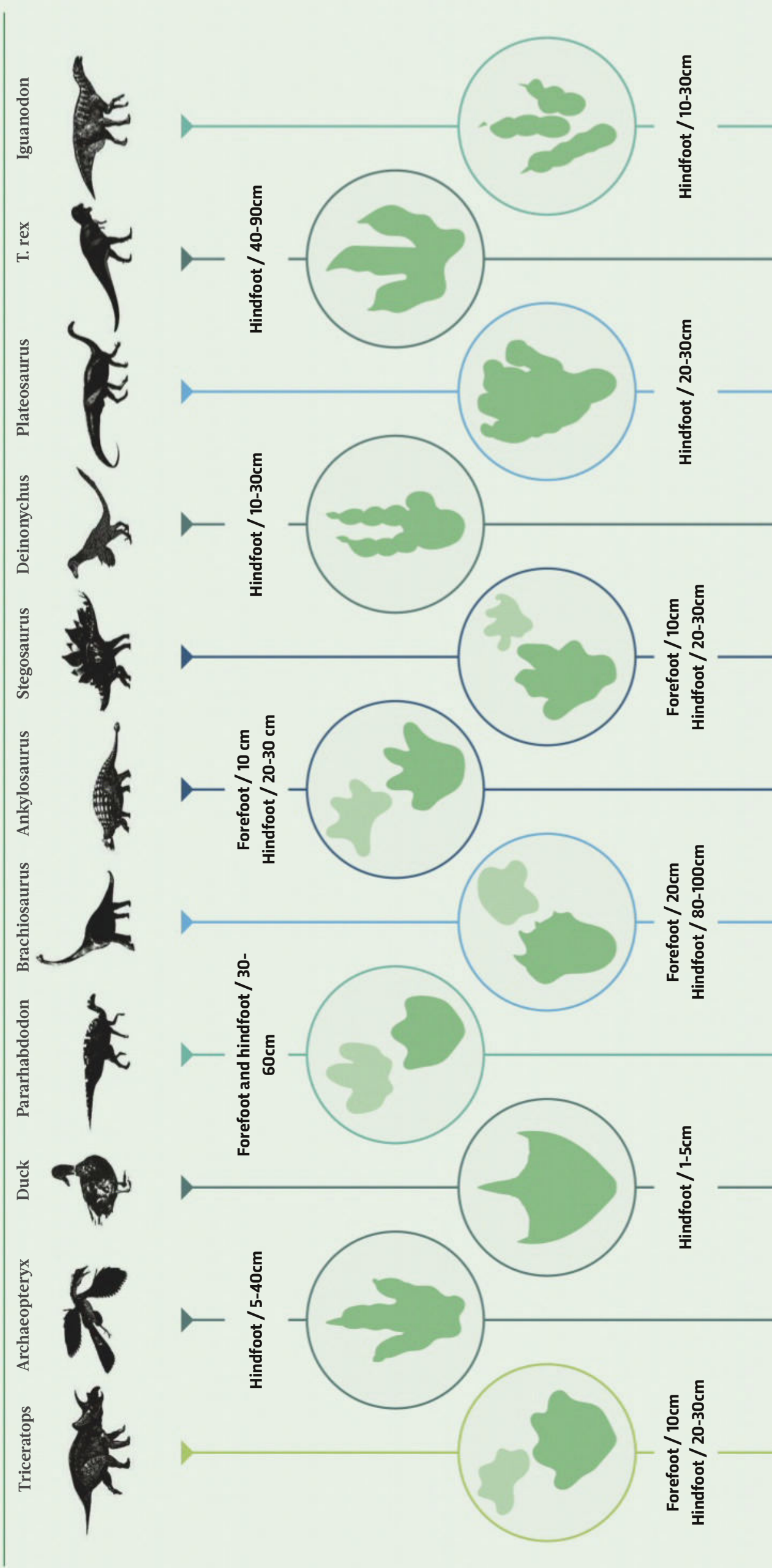
◆

Ornithopods
'Bird-footed' herbivores

The average length of a male human hand and foot is 19cm and 27cm respectively.

◆

Sauropodomorphs
Long-necked herbivores



LATE TRIASSIC
237 TO 201 MILLION YEARS AGO

EARLY JURASSIC
201 TO 174 MILLION YEARS AGO

MID JURASSIC
174 TO 163 MILLION YEARS AGO

LATE JURASSIC
163 TO 146 TO MILLION YEARS AGO

EARLY CRETACOUS
146 TO 100 MILLIN YEARS AGO

MID/ LATE CRETACOUS
100 TO 66 MILLION YEARS AGO

Smaller theropods

Theropods or predatory dinosaurs generally had four-toed feet where all the weight was borne on the three longer toes. These were slim, had pointed claws, and could spread wide apart.

Birds

Birds – a theropod subgroup – produce smaller tracks than those of other theropods, typically a few centimetres long. Webbing is common, as are toes that can spread especially far apart.

Ceratopsians

Ceratopsians, or horned dinosaurs, like *Triceratops*, had five-fingered hands. The short outer fingers hardly touched the ground. Their hindfeet were broad, with four short toes and blunt claws. Early ceratopsians were small bipeds and must have left narrow-footed tracks.

Hadrosaurs

The giant ornithopods of the Cretaceous – *Iguanodon*, and the duckbills or hadrosaurs – were three-toed, with thick toes and hoof-like claws. They also walked on all fours, and their forefeet produced small, crescent-shaped tracks.

Sauropods

Sauropods made semi-circular forefoot tracks. These sometimes include marks made by an inward-pointing thumb claw. Their hindfoot tracks are larger, rounded and preserve the impressions of three big, curved claws.

Ankylosaurs

The tracks of ankylosaurs are rare. They walked on the ends of their fingers and kept the palm near-vertical, so their forefoot tracks are short. The longer hindfeet were three- or four-toed depending on species.

Prosauropods

These Triassic and Early Jurassic dinosaurs produced long, four-toed tracks. Their foot claws were large and the pads on their toes were prominent. Some species occasionally brought the hands into contact with the ground.

Dromaeosaurs

Dromaeosaur tracks are unique and consist of a rounded foot pad, the impressions of two long, clawed toes and a rounded impression made by the base of the second toe.

Large theropods

Tracks made by giant theropods – like the 12-metre *Tyrannosaurus* – are known but rare. They reveal thicker, chunkier toes and bigger fleshy pads than those present on smaller theropods.

Stegosaurs

The giant ornithopods of the Cretaceous were three-toed, with thick toes and hoof-like claws. They also walked on all fours, and produced small, crescent-shaped hand tracks.

Small ornithopods

Many ornithopods were small and mid-sized, bipedal plant-eaters. Like theropods, they walked on their three longest toes. Their toes tended not to spread as far apart as those of theropods.

MEET THE OROBOT

OroBOT is a sophisticated robot, carefully designed to mimic the anatomy and walking behaviour of *Orobates*

To make study easier and house the robotics, OroBOT is about 1.6 times larger than the real *Orobates*. OroBOT is 1.4m long.

Sensors placed throughout OroBOT's structure keep track of the position of its limbs.

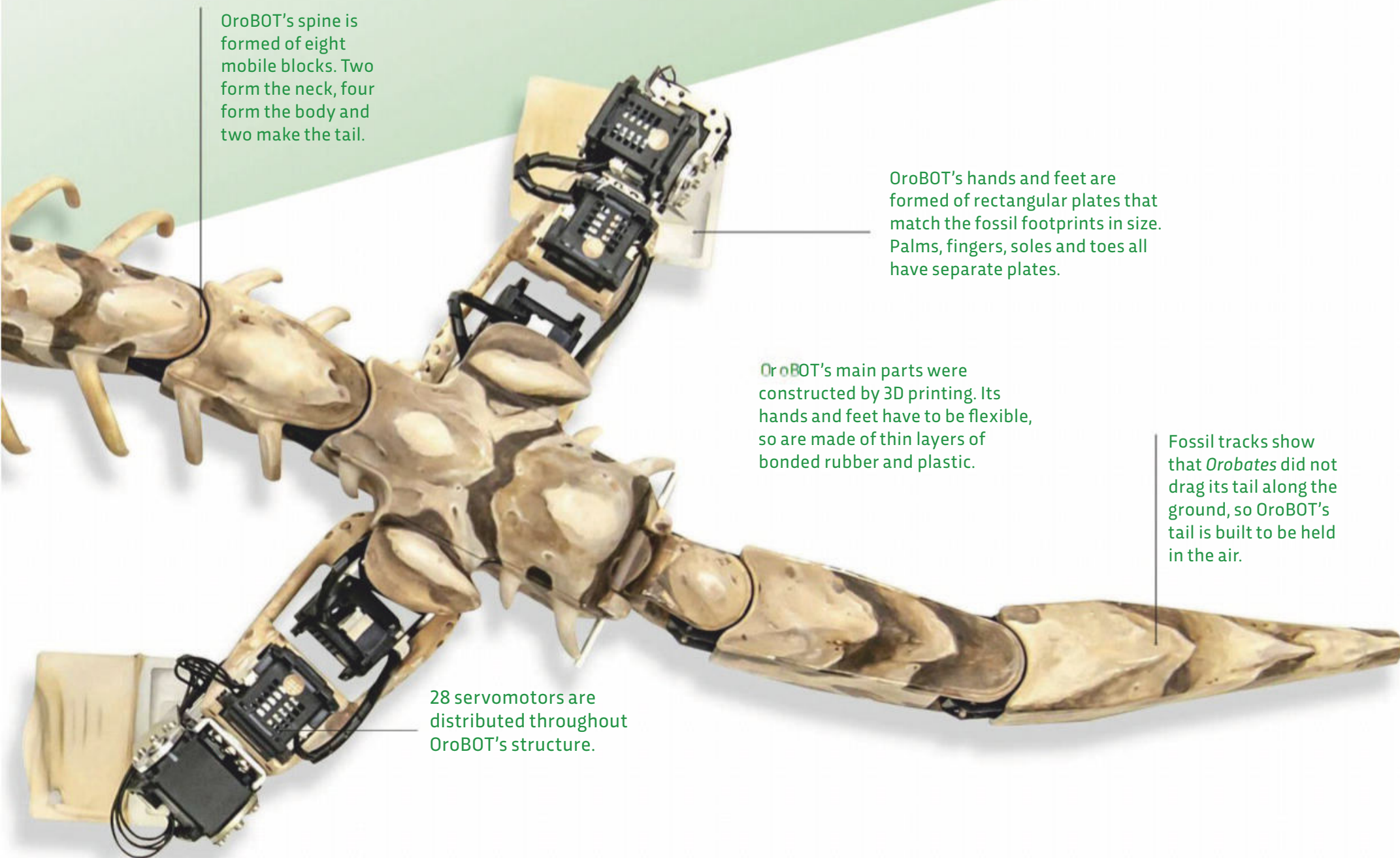
Mobile joints in all limbs give OroBOT flexible shoulder, elbow and wrist joints in the forelimb, and hip, knee and ankle joints in the hindlimb.

“SOME OF THE GAITS CAUSED OROBOT TO LOSE ITS BALANCE OR BANG ITS LIMBS TOGETHER”

► Data from living animals can be used to show how efficient given walking styles and limb postures are. The team used information from four living animals (a salamander, a skink, an iguana and a caiman) to determine which of OroBOT's postures and poses were biologically most likely. They also measured the robot's centre of mass and the way it distributed its weight across the different segments of its body. The team measured 512 gaits and mathematically scored them according to how well they performed based on our understanding of what real animals do.

“We explored a large number of potential gaits and evaluated these according to anatomical plausibility and other factors, all of which were tested in the robot,” says Nyakatura. Some of the gaits caused OroBOT to lose its balance, bang its limbs together or put too much strain on its joints and so were considered unlikely to have been used by the living animal. Also, living animals tend to use gaits where relatively little energy is required to move their joints, so gaits that were found to be inefficient were also deemed to be unrealistic.

Surprisingly, OroBOT's highest scoring gaits involved it walking with a tall, erect-limbed stance where its body was held high off the ground and its limbs were held relatively close to the body, albeit sprawled out. This resembles the walking gait used by iguanas and caimans rather than that of salamanders and short-limbed lizards like skinks. This



OroBOT's spine is formed of eight mobile blocks. Two form the neck, four form the body and two make the tail.

OroBOT's hands and feet are formed of rectangular plates that match the fossil footprints in size. Palms, fingers, soles and toes all have separate plates.

OroBOT's main parts were constructed by 3D printing. Its hands and feet have to be flexible, so are made of thin layers of bonded rubber and plastic.

Fossil tracks show that *Orobates* did not drag its tail along the ground, so OroBOT's tail is built to be held in the air.

28 servomotors are distributed throughout OroBOT's structure.

means that *Orobates* – and presumably other diadectids as well – walked in an efficient, ‘modern’ fashion more reminiscent of advanced reptiles such as crocodilians, not with the less efficient, seemingly clumsier gait assumed by previous studies.

WALKING TALL

What this indicates is that tetrapods had evolved a sophisticated, complex way of moving on land relatively early in their history, prior to the evolution of amniotes.

Rather than being clumsy prototypes of amniotes, diadectids – and presumably the tetrapods related to them too – were already quite capable on land, as the features of their gait, posture and efficiency suggest. Diadectids and similar tetrapods were, it now seems, probably faster, more efficient and had better balance and coordination on land than had been assumed before.

The beauty of this study is both that it uses multiple different techniques

and lines of evidence to examine the gait of a long-extinct animal and proposes numerous possibilities, some of which provide more satisfying, more realistic results than others. The findings are compelling enough to show how reliable and useful this technique is, and ultimately mean that the locomotion of this interesting and important early tetrapod has effectively been reverse engineered with the help of biorobotics.

“We give a range of possibilities and provide some powerful tools and datasets so that others can replicate and visualise our results,” says Hutchinson. “We hopefully show how multiple lines of evidence – footprints, skeletons, digital animation, experiments with living animals, robots and computer simulations, essentially a kitchen sink of techniques – can be combined to tackle similar questions with other organisms in the future.”

So, what's next? The success of this technique, and of OroBOT itself, means that work of this kind will surely be applied to other ancient animals, some of which come from crucial parts of evolutionary history or are unusual and mysterious because they're so different from living animals. “I'd love to see someone try this with a walking Triassic pterosaur,” says Hutchinson. **SF**

by **DR DARREN NAISH**
(@TetZoo)

Darren is the author of *Evolution In Minutes* (£9.99, Quercus).

DISCOVER MORE

BBC
RADIO

4

In this clip from *How To Build A Dinosaur*, find out more about how studying the anatomy of today's animals is informing our understanding of the ways dinosaurs moved. bit.ly/dino_loco



→ Sir David Attenborough: surrogate grandfather to millions of people around the world

HOW TO SAVE THE WORLD

THIS MONTH, SIR DAVID
ATTENBOROUGH REUNITES WITH
THE CREATORS OF *PLANET EARTH*
FOR NEW NETFLIX SERIES *OUR
PLANET*. HERE, THEY REVEAL HOW
THE SHOW WILL INSPIRE PEOPLE
TO SAVE OUR BEAUTIFUL HOME...

**WHAT MAKES *OUR PLANET* DIFFERENT FROM
OTHER NATURAL HISTORY SHOWS THAT
YOU'VE WORKED ON?**

Alastair Fothergill: Having completed *Planet Earth*,
Blue Planet and *Frozen Planet*, the time was right
to do a series that dealt with our planet's
environmental and ecological challenges. If there's

any chance of preserving biodiversity, what are the
'must-saves'?

Keith Scholey: In the grasslands episode, for
example, it's about space. Most of the great
migrations have disappeared because we took that
space away. We say, "If you want to make space for
grasslands, this is what you have to do." It's ►

BBC



"I CAN'T THINK OF A MOMENT THAT HAD MORE EFFECT ON ME THAN THE FIRST TIME I DIVED ON THE BARRIER REEF"

● actually quite simple – it's all about the food we eat. If people change their diet or we change the way we produce food, we can have a huge amount more space for nature. This is the principle of the whole series. Then, within each show, we highlight individual animals. Like the orangutans in the jungles of Borneo: if we carry on the way we are, this will be the last generation of wild orangutans. That's about space.

YOU'VE EXPLORED THE NATURAL WORLD MORE THAN MOST, BUT YOU'VE ALSO WITNESSED ITS DESTRUCTION FIRST HAND. FROM THAT, WHAT HAVE YOU LEARNED THAT WE SHOULD KNOW?

David Attenborough: Everybody should realise that this is not just because I like dicky birds. You, me and the rest of the human species are critically dependent on the health of the natural world. If the seas stop producing oxygen we would be unable to breathe, and there is no food that we can digest that doesn't originate from the natural world. If we damage the natural world, we damage ourselves.

KS: Most people think there's nothing we can do, it's just lots of tiny problems. But there are some very big, simple things that you need to sort quickly, which can fix so much of this.

The ocean is a classic example. The open ocean is going down the tube, largely because of overfishing. But there are only about four or five nations who fish the open ocean, and it has to be subsidised because it's so unprofitable. So why not just stop doing it? The open ocean is probably the biggest carbon sump – one of our biggest weapons in dealing with climate change.

AF: When we started, conservation was about preserving pandas and national parks. I think the big change is the recognition that things are beginning to break down globally because we've lost so much biodiversity. If the planet is going to recover, the main thing it needs for that recovery is biodiversity.

KS: There was a very alarming report this week about the loss of insects. Insects are the fabric of the world. They pollinate. You can't have soil without insects. Nature is no longer just nice to have, it's essential.

YOU'VE BEEN BACK TO THE SAME PLACES TO FILM, DECADES APART. WHAT'S CHANGED?

AF: I worked in Antarctica for a series called *Life In The Freezer* and then *Frozen Planet*. Different penguins in Antarctica are adapted to different amounts of ice. The Adélie penguin feeds around and under ice in the Antarctic peninsula, which is this long arm that sticks north and has been most affected by climate change. The Adélie penguin has now become much rarer, and is only found in the deep south, and it's been replaced by the gentoo penguin, which breeds on the Falkland Islands and South Georgia.

KS: In the 1960s in Kenya, everywhere you drove there was wildlife – cheetahs, lions, just off the main roads. Now, it's completely confined to national parks. The vast majority of wildlife outside has gone, and that's a staggering change in just 50 years.

IS THERE ONE NATURAL PHENOMENON YOU ESPECIALLY WANT YOUR GREAT-GRANDCHILDREN TO BE ABLE TO SEE?

DA: The Great Barrier Reef, easy answer. I can't think of a moment that had more effect on me than the first time I dived with an aqualung on the Barrier Reef. It was 1956, the gear we had was clunky, and my skills were almost non-existent. Diving is a transforming feeling. Suddenly you're no longer anchored to the ground, and when you look down there are 500 different species of creatures, just there, and you've never seen anything like it ever before. They're the most wonderful colours. Some of them are fish but others – you have no idea what they are! And ●

Sir David Attenborough

Sir David Attenborough is a broadcasting icon with more than half a century of experience under his belt. He first brought the world of wildlife into our living rooms with BBC's *Zoo Quest* in the 1950s, and since then has been renowned for *The Life Collection*, *The Blue Planet*, *Planet Earth* and numerous other documentaries. He's the only person to scoop BAFTA awards for black and white, colour, HD, 3D and 4K television, is an enthusiastic cheerleader for the environment, and will be narrating Netflix's *Our Planet* this spring.

Alastair Fothergill

Alastair Fothergill is a producer of nature documentaries who used to head up the BBC's Natural History Unit, before starting his own production company with Keith Scholey (below) in 2012. He previously worked with Sir David on *The Blue Planet* and *Planet Earth* and is working with him once again on *Our Planet*.

Keith Scholey

Keith Scholey is joint series producer of *Our Planet*, along with Alastair Fothergill. He has worked on landmark series like *Wildlife On One*, *The Private Life Of Plants*, *The Blue Planet*, *Springwatch* and *Planet Earth*. Like Alastair, he also used to head up the BBC's Natural History Unit. He later went on to be controller of specialist factual at the BBC.



→
Sir David
Attenborough
wants his
great-grandchildren
to experience the
joys of scuba diving
before it's too late



🔊 they're all absolutely preoccupied with their own things, they take very little notice of you. That is an experience you'll never forget!

KS: Coral reefs are the most incredible things you can ever witness, and future generations might not be able to experience them. This is an ecosystem that has taken hundreds of millions of years to come about: it's the most exquisite, beautiful and complex thing that nature has ever created, but it can go in a couple of centuries.

And the big migrations of Africa: seeing big animals roam, and lions jump on buffalo, and cheetahs chase gazelles. To be able to see nature as it was, existing with nothing to do with us, is another thing that we have to keep.

AF: You look into the eyes of a chimpanzee and you know that it's an intelligent, thinking being. And polar bears. There's a good chance that polar bears will basically go extinct within 40 years. There may be a few relic populations, but to think the largest land carnivore on our planet would be gone, that's heart-breaking.

DO YOU FEEL OPTIMISTIC OR PESSIMISTIC ABOUT THE FUTURE OF THE NATURAL WORLD?

DA: I feel that the world is more aware of what the problems are than it has been for most of my career. Fifty years ago people didn't think there was a problem – and there *wasn't* a problem that's commensurate with the problem we have now. But the problem has got bigger, that's the difficulty.

There's a big responsibility that natural history filmmakers have. I'd love to spend the whole time saying, "Look at these wonderful things, aren't they lovely?" But you have a responsibility for pointing out that unless we change our ways, they're not going to be here for ever.

KS: I'm optimistic, as long as we can motivate people to do things quickly. Time has gone. We have to motivate change. The penny is dropping, and lots of big businesses and governments are prepared to start to change. But the race against time is acute. If we prevaricate, for even a few more years, we have lost the game.

AF: The human species is extremely clever. We're very good at fixing things, and there's absolutely no



doubt that there is technology out there to solve almost all of our problems. I agree with Keith that, optimistically, it's within grasp. Politically, it's more challenging. What we do in the next 20 years is vital.

WHAT ARE THE MAIN THINGS THAT ARE STOPPING THESE SOLUTIONS?

KS: There's a failure to realise the scale of the problem. Climate change is a massive beast that's

1. *Our Planet* will explore stunning environments, focusing on the diversity of different habitats

2. The instantly recognisable Sir David Attenborough will be narrating the new series

✕
"YOU COULD ARGUE THAT PEOPLE LIKE TRUMP ENCOURAGE ENVIRONMENTALISM. LOOK AT THE NEW PRESIDENT OF BRAZIL; NEVER HAS PROTECTION OF THE AMAZON BEEN MORE TALKED ABOUT"



going to bite everyone very badly. If it runs out of control, it's far more dangerous than anything else you could ever face. We have to recognise what the biggest problem is, then invest in solving it. We've got the resources we need.

AF: Global economies are based too much on short-term gain rather than long-term sustainability. Davos was such an amazing opportunity for us, because it's a forum of economists and business leaders who are beginning to realise that if you want a sustainable business, you have to have a sustainable resource. They're all based on a resource in the natural world, none of them can escape that. There is no political problem that mankind has ever faced that's as important as the one we're now facing.

DA: It has to be done with international agreements. But it's not easy, and it has never really been done, except for the whaling agreement. With the whaling agreement, for the first time, seagoing nations around the world got together, saw the danger and said, "Right, we'll stop whaling." If we can achieve that, we can achieve other things too.

All we can do is find the people who have fingers on the right levers, and make sure they hear our message. Whatever you say about Davos, there were a lot of people there with their fingers on some very big levers. What governs the way they think? Their own conscience, I suppose. So you go and say: these are the problems. If you've got the opportunity to do that, you'd better bloody well do it.

THERE ARE SOME POLITICIANS, DONALD TRUMP, FOR EXAMPLE, WITH FINGERS ON BIG LEVERS

DISCOVER MORE



ON THE PODCAST

You can listen to the full interview with David Attenborough, Alastair Fothergill and Keith Scholey at sciencefocus.com/science-focus-podcast



WATCH

Our Planet is launching on Netflix on 5 April.



WHO AREN'T WORKING FOR THE GOOD OF THE ENVIRONMENT. WHAT WOULD YOU SAY TO THEM?

DA: I would do the same as I do to anybody else – I would say, these are the facts. But there are some people who are never going to change their opinion, and it could well be that Mr Trump is one of them. If you're in a democratic society, you convince the electorate that you're right, and try to put people in power who see the truth.

AF: When Donald Trump pulled out of Paris, a lot of conservationists thought it was a disaster. Ironically, green issues have never been more powerful in the States. The governor of California – the ninth biggest economy on the planet – said that Donald Trump can say what he likes, we are going to be the most green economy we can. You could argue that people like him encourage environmentalism. Look at the new president of Brazil; never has protection of the Amazon been more talked about.

KS: Most politicians now have to think very carefully about whether they want to end up on the wrong side of history. Can you look your grandchildren in the eye and say, "I ignored this, I did nothing."?

AF: The other thing that will [create] change is men and women in the street who say, "I'm not going to buy a computer that's not green. I'm not going to eat as much meat." Our ambition [with *Our Planet*] is to communicate to a billion people, and that isn't over-optimistic. We have immense power.

Take the example of plastics in *Blue Planet II* – within a month, government was changing policy. We have a voice, and together we can really put pressure on politicians.

DID YOU FEEL, AT DAVOS, LIKE THE POLITICIANS WERE LISTENING?

DA: It would be naive to think suddenly that you can say something, and these enormously powerful men and organisations are going to change overnight. The world doesn't work like that.

But there are groundswells; there are these great sea changes that are difficult to plot, but they do happen. It's up to us to bring that about. Whether we will succeed is almost neither here nor there – you simply have this obligation to try. **SF**



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COMMENT

WHY DO YOU THINK THEY CALL IT JUNK?

Processed foods and takeaways could be to blame for the UK's obesity epidemic

We know that takeaways and highly processed foods are bad for us, but just how bad? I've recently been involved in a TV programme, *The Junk Food Experiment*, in which we asked six British celebs to live on a junk food diet for three weeks.

What was so disturbing was just how quickly our guinea pigs became sick, to the point where the series doctor told three of the celebs – Olympic athlete Tess Sanderson, *Made In Chelsea* star Hugo Taylor and actress Hayley Tammadon – that they had to pull out. In Tessa's case, it was because her blood pressure had risen so high there were fears she would have a stroke. Hayley developed severe symptoms of irritable bowel syndrome and was in such pain she couldn't continue, while Hugo became so anxious on the diet he also had to stop.

Although this documentary involved only a small number of subjects, it did point to a wider truth: junk food has a far more insidious effect on us than most people imagine.

The most obvious link is obesity. We Brits, lovers of fast food, are the fattest people in Europe. We put away around 22 million takeaway meals a week, and the number of junk food outlets on our high streets continues to soar – up a third since

✕ **“We Brits, lovers of fast food, put away around 22 million takeaway meals a week”**

2010 to more than 52,000 – while processed foods such as snacks, desserts or ready-to-eat meals now comprise more than half the diet of the average adult in Britain.

Yet a recent study by scientists at the Paris-Sorbonne University found that for every 10 per cent increase in our intake of these foods, the risk of dying prematurely increased by 14 per cent. In another US study, 20 adults of healthy weight were asked to come into a lab and live for two weeks on processed foods, followed by two weeks of healthy,

home-cooked meals. Although the different meals contained roughly the same amounts of fat, sugar, salt and carbs, volunteers ate, on average, 500 more calories a day when eating processed foods than when eating real food. As a result, they put on an average of 0.77kg (1.7lbs) on the processed diet, while they lost 1.08kg (2.4lbs) on the healthy regime.

Piling on the bad news, in another recent report a team from California's Loma Linda University reviewed data from over 240,000 telephone surveys, and found that consumption of fried takeaway foods and those containing lots of sugar was strongly linked with depression, even when they took age, education and income into account.

In the light of all this new research, surely it's time that governments stepped in to curb the excesses of Big Food in the same way we have legislated against tobacco. **SF**



MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800* (£8.99, Short Books).



COMMENT

A SOCIAL CURSE

Misinformation reinforces the fear of the unknown

French President Emmanuel Macron must have been mistaken when he recently described nationalism as the leprosy spreading across Europe – unless he meant it was really slow-moving, easy to treat, and harmless to everyone but a few. But I don't think he did mean that.

I think that, like most people, he doesn't understand the disease. He probably just thinks that 'leprosy' is shorthand for 'biblical curse'. But that's a problem. Because despite being well understood by people in the medical community who treat it, leprosy – or to give it its correct name, Hansen's disease (HD) – is so misunderstood by many people that comments like Macron's reinforce the fear of the unknown, and destroy lives that could otherwise be saved with a simple antibiotic.

I grew up surrounded by leprosy from the time I was six, but I've never had it. In fact, no one in my family has. It's really hard to catch. Ninety-five per cent of the population is immune, and the biological organism that causes it, *Microbacterium leprae*, is slow to move from one susceptible person to another. As I mentioned, it's also treatable. The cure was found in 1943, at the hospital my dad worked at in the second half of his career.

Dad was a tropical disease specialist. He met my stepmother at the US government's National Hansen's Disease Center in Carville, Louisiana; she lived on the grounds



“The true curse of Hansen’s disease is not spiritual in nature. It certainly isn’t medical. It is entirely social”

with her son before she and Dad got married. She worked with patients who had the typical disabilities associated with the untreated disease, like clawed hands and feet, and facial disfigurement – all parts of the nervous system that *M. leprae* attacks. She touched people with HD every day. Dad worked directly with the bacterium. They never caught it.

And if they had, they would have been treated. It would have been a footnote in their medical histories, just like it is for BB, a woman I interviewed for a BBC World Service programme about the disease. BB was diagnosed as a teenager. Maybe what saved her is that she lived in Baton Rouge, which is 24km

(15 miles) away from Carville. The doctor who looked at the funny rash on her ankle knew it might be Hansen's because people there knew about it. She was treated. No more Hansen's.

Further from the epicentre of Carville, Hansen's is mostly known as a mythical illness, possibly sin-related. Many people – doctors included – think it doesn't exist any more. I interviewed Francis. He was in a wheelchair, and was severely disabled. A decade ago, he started having agonising pain in his hands and feet. He went to the hospital in Portland, where he lived. They had no idea what it was. He suffered for the next 10 years, as his able body was broken down by the ailment that no one in his city could diagnose. Three months ago he got the formal diagnosis and was transported for treatment to Baton Rouge.

The true curse of having Hansen's disease is not spiritual in nature. It certainly isn't medical. It is entirely social. And to beat it, we have to stop using words that are intended for powerful, political effect. **SF**

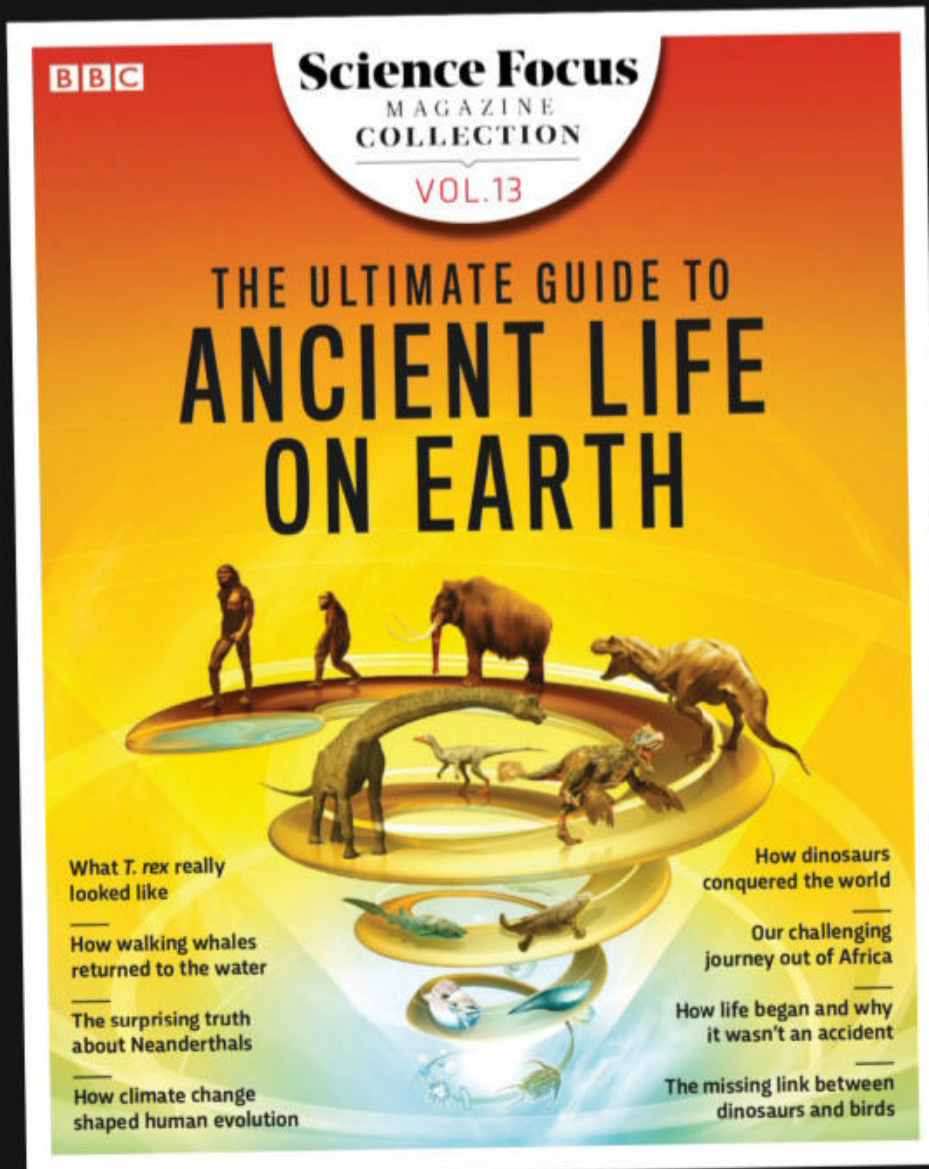


ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.



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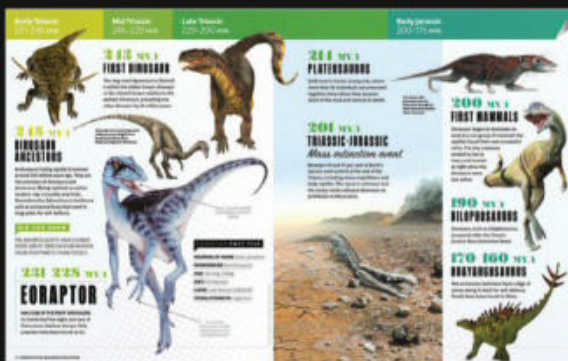
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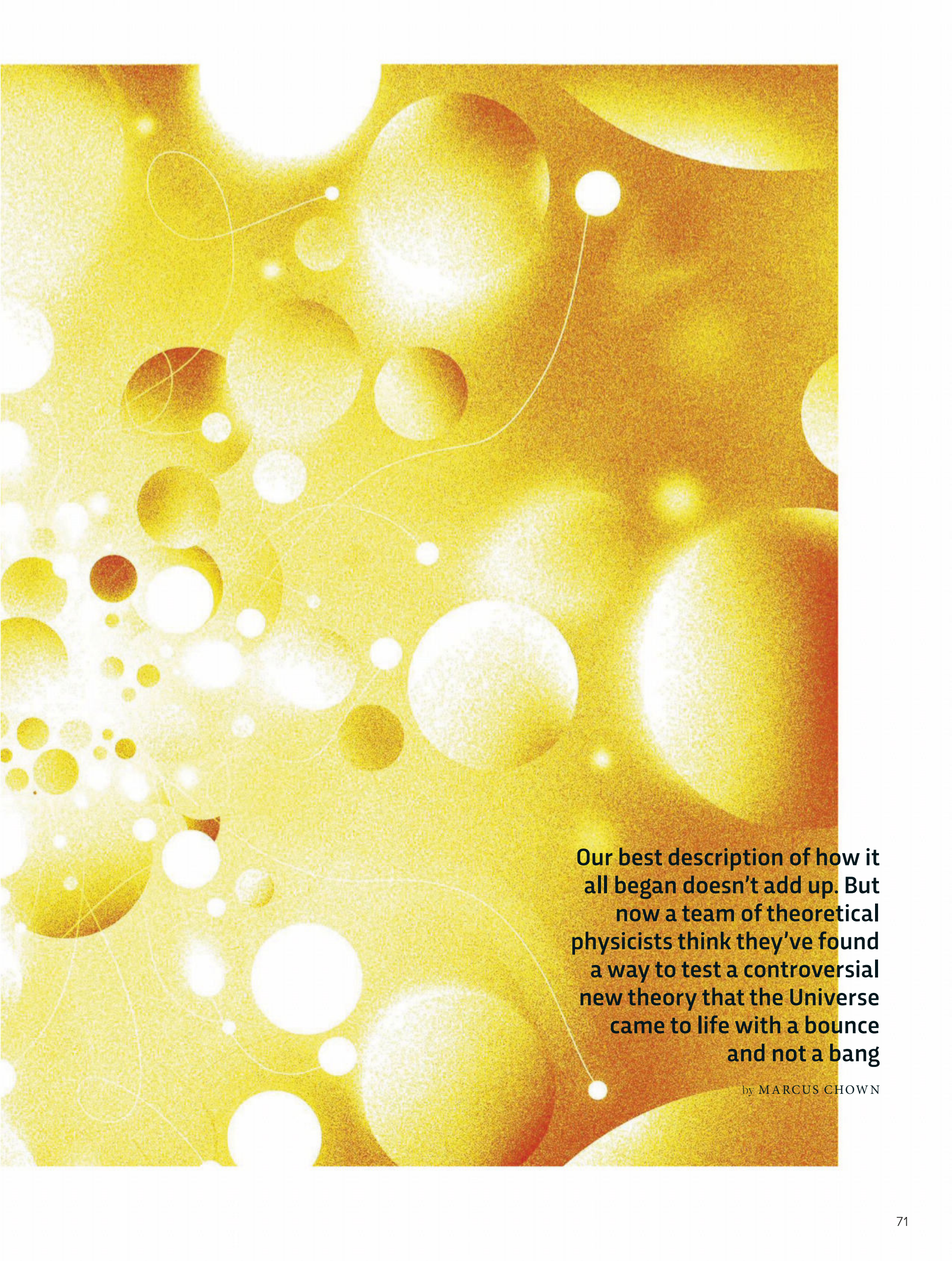
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The background is a vibrant, abstract composition of various-sized circles and dots in shades of yellow, orange, and white. Some circles are solid, while others are outlined or have a textured, grainy appearance. The overall effect is reminiscent of a cosmic or cellular structure, with some elements resembling a network or a cluster of particles.

WHAT IF THE BIG BANG WAS NOT THE BEGINNING?

ILLUSTRATION: OTHER PETER

The background of the page is a vibrant, abstract composition. It features a dense field of overlapping circles in various shades of yellow, gold, and orange. Some circles are solid, while others are outlined. Thin, white, curved lines weave through the circles, creating a sense of movement and depth. The overall effect is reminiscent of a cosmic or cellular structure.

**Our best description of how it
all began doesn't add up. But
now a team of theoretical
physicists think they've found
a way to test a controversial
new theory that the Universe
came to life with a bounce
and not a bang**

by MARCUS CHOWN

The greatest discovery in the history of science is that there was a day without a yesterday. The Universe has not existed forever. It was born. All matter, energy, space and even time, burst into being in a titanic fireball we call the Big Bang, 13.82 billion years ago. The fireball expanded and, out of the cooling debris, there congealed the galaxies – great islands of stars; two trillion of them, of which our Milky Way is but one.

Whatever way you look at it, the idea of the Universe popping into existence like a rabbit out of a hat is bonkers. For this reason, scientists

had to be dragged kicking and screaming to it. The last thing they wanted to answer was the awkward question: what happened before the Big Bang?

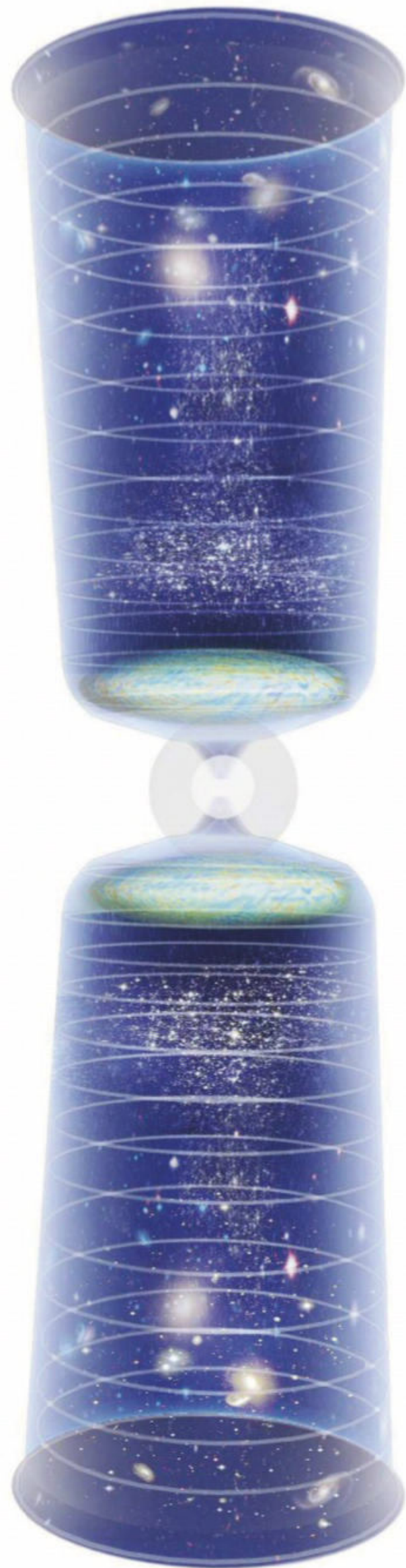
In recent decades, the idea has taken hold that the Universe began with an ultra-brief burst of super-fast expansion. So violent was this ‘inflation’ that it’s been likened to the explosion of an H-bomb compared with the mere stick of dynamite of the more sedate Big Bang expansion that took over when inflation ran out of steam. But now a prominent American astrophysicist is questioning the inflationary orthodoxy and advocating a fresh look at alternative models in which the Big Bang was actually a ‘big bounce’ from an earlier, contracting, phase of the Universe. “Crucially, my colleagues and I are proposing an observational test capable of distinguishing between the possibilities,” says Prof Abraham Loeb of the Harvard-Smithsonian Center for Astrophysics.

INEXPLICABLY BIG GAPS

One cosmic observation that any scenario must explain is why the Universe is so remarkably uniform: specifically, why the temperature of the heat afterglow of the Big Bang is pretty much the same everywhere and why the number of galaxies in a given volume is also the same everywhere. This is a puzzle because if the expansion of the Universe is imagined running backwards to the Big Bang, like a movie playing in reverse, it becomes clear

RIGHT The Big Bounce describes the idea that the Universe’s rapid expansion was a reaction to a period of rapid contraction

ABOVE RIGHT Prof Alun Guth, the ‘father of inflation’





that regions of the Universe that today are widely separated were not in contact with each other at the beginning. In other words, there has been insufficient time since the birth of the Universe for any influence travelling at the cosmic speed limit (the speed of light) to pass between them. How, then, could heat have passed between such regions in order for their temperatures to equalise?

“WHATEVER WAY YOU LOOK AT IT, THE IDEA OF THE UNIVERSE POPPING INTO EXISTENCE IS BONKERS”

The standard explanation is that the Universe was far smaller early on than we imagine if we run that movie in reverse. If it was smaller, then bits of the Universe that are today widely separated would have been closer together. But, if the Universe started off smaller earlier on, it must have expanded faster in order to reach its current size in 13.82 billion years.

Such a period of super-fast expansion, occurring in the first split-second of the Universe’s existence, was proposed by the Russian physicist Alexei Starobinsky in 1979 and the American physicist Prof Alan Guth in 1980. This inflation was driven by the vacuum. Not the vacuum that we see around us today but a super-high-energy version. This was because the ‘inflationary vacuum’ contained a so-called scalar field, which, in common with the Higgs field, discovered at the Large Hadron Collider near Geneva in 2012, had a non-zero energy everywhere.

The super-high-energy inflationary vacuum had some remarkable properties. First, it had repulsive gravity, which caused it to expand – and the more of it there was, the greater was its repulsion and the faster it expanded. Second, when the inflationary vacuum doubled its volume, it doubled its energy; when it tripled its volume, it tripled its energy and so on. Imagine if you had a stack of banknotes between your hands and you pulled your hands apart and the result was the creation of more banknotes. Physicists, not surprisingly, refer to inflation as the ‘ultimate free lunch’.

But the inflationary vacuum, which contained energy but not matter, was ●

• a ‘quantum’ thing (quantum theory is our best description of the microscopic world of atoms and their constituents). And quantum things are fundamentally unpredictable. So, at random locations all over the inflationary vacuum, bits ‘decayed’ into normal, everyday vacuum. Picture it as a vast ocean in which bubbles form. Inside each bubble, the enormous energy of the inflationary vacuum had to go somewhere. It went into creating matter and heating it to a ferociously high temperature – in short, into creating a big bang. We live inside one of these big bang bubbles in the inflationary vacuum.

In this picture, the Big Bang is not a one-off event. Big bangs are going off like fireworks across the inflationary vacuum. And all this could have been started by a small piece of inflationary vacuum – with a mass-energy of as little as a kilogram – popping into existence out of nothing, which, incredibly, is permitted by the laws of quantum theory. Inflation, once started, goes on forever since new vacuum is created faster than it’s eaten away.

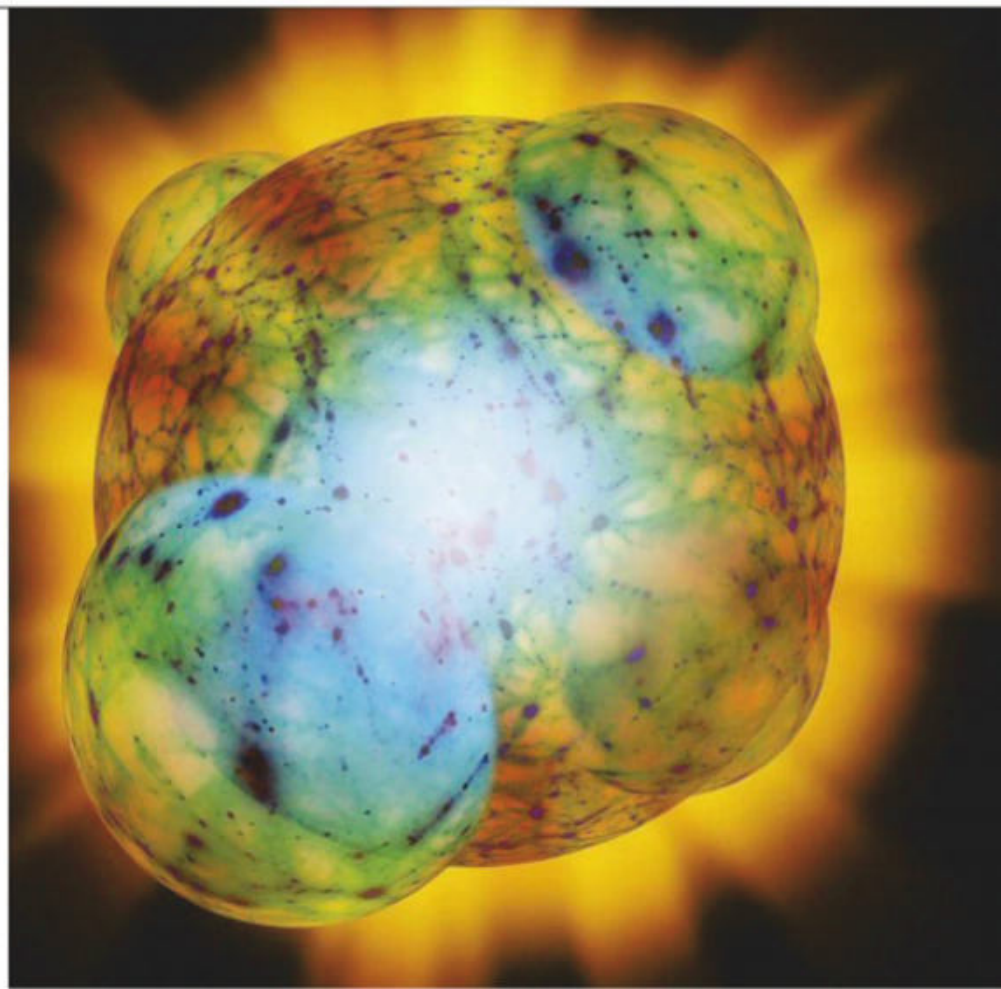
But, according to Loeb, the inflationary scenario has problems. “After 40 years, we have no evidence of the existence of the ‘inflaton’ field that drives inflation, as we do of the Higgs,” he says. Also, there is an infinity of ways in which the inflaton field can decay, exiting inflationary expansion and starting Big Bang expansion. Physicists imagine a mathematical ‘potential’, rather like a ski slope, down which the inflaton field slides, reducing its energy to zero. But the ski slope can have a different shape in different locations. “This means that inflation will continue for longer in some places than others, greatly changing nature of the resultant space-time,” says Loeb. “Inflation therefore predicts the existence of an infinity of domains, each with different physics – a ‘multiverse’.”

The problem is that our Universe doesn’t have the properties of a typical member of the multiverse. “Our universe is exceedingly dilute in vacuum energy relative to a typical

region in the multiverse,” says Loeb. We are therefore forced to explain its special properties, such as dark energy, with the topsy-turvy logic of the ‘anthropic principle’: that we live in the domain we live in because, if we didn’t, the physics would not have given rise to stars and galaxies, and physicists to describe them. “This gives inflation no explanatory power,” says Loeb. “It’s an infinitely flexible framework capable of fitting any data. To my mind that means it is not science.”

This claim, made by Loeb, Anna Ijjas and Prof Paul Steinhardt in a 2017 article in *Scientific American*, caused a storm of controversy. According to ‘the father of inflation’ Prof Alan

ABOVE Inflation decays at different rates in different locations, leading to ‘bubbles’ in the inflationary vacuum, in other words, creating the potential for a multiverse



“IN THIS PICTURE, THE BIG BANG IS NOT A ONE-OFF EVENT. BIG BANGS ARE GOING OFF LIKE FIREWORKS ACROSS THE INFLATORY VACUUM”

THE CYCLIC UNIVERSE

In, out, in, out... Are we trapped in a Universe that's dancing an endless Hokey-Cokey?

Guth of the Massachusetts Institute of Technology: "The comment that inflationary cosmology, as we currently understand it, cannot be evaluated using the scientific method seemed so far removed from reality that 32 leaders in the field of cosmology, including five Nobel Laureates, and I wrote a letter to the editor categorically disagreeing with the statements made by this article about the testability of inflation."

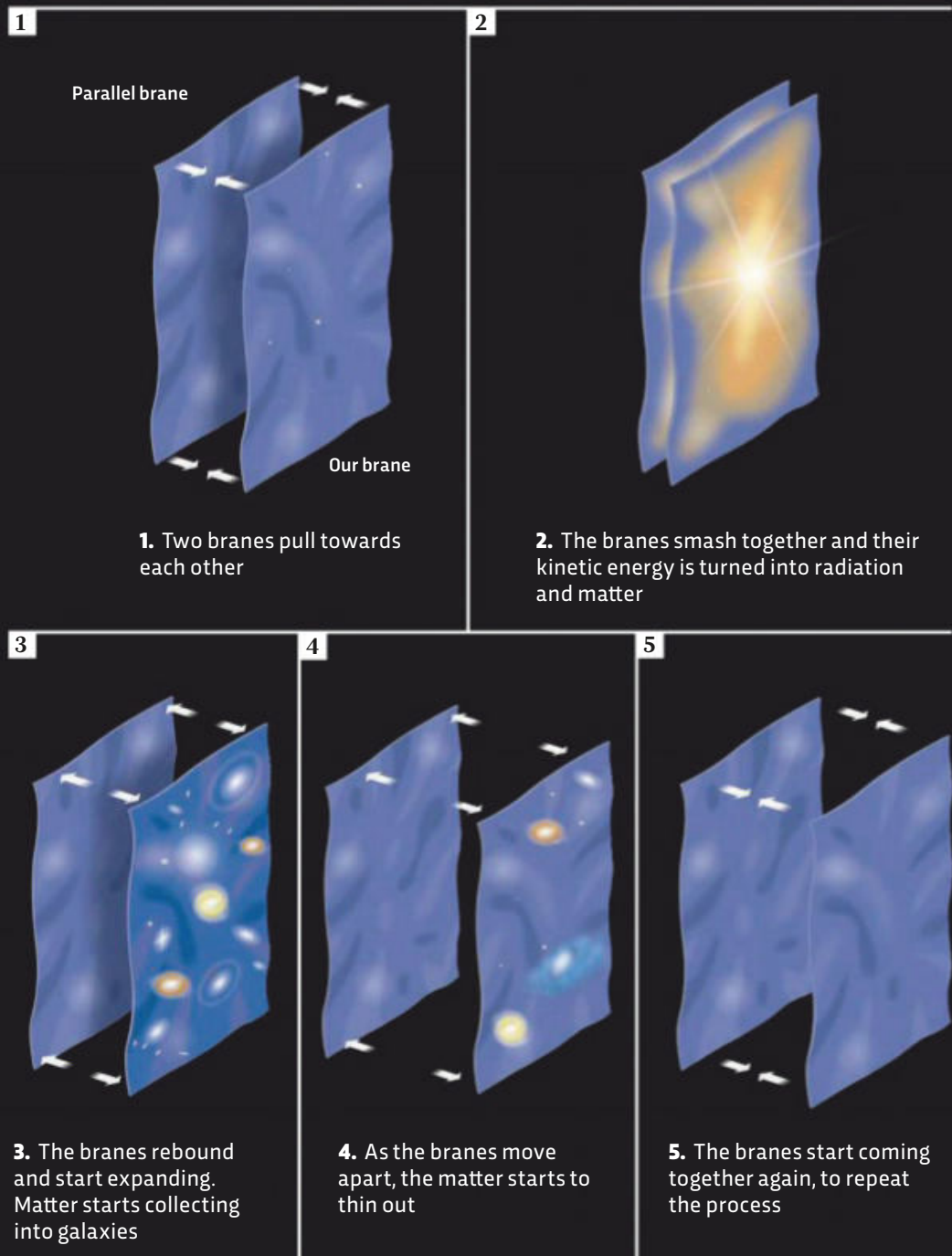
"That's quite depressing," says Loeb. "If a scientific idea is wrong, it needs only one person to point out why it's wrong. Scientific truth is not decided by authority but by nature itself."

Loeb thinks that inflation, like 'string theory' (a candidate for a theory of everything) has evolved over a long time in the absence of serious experimental tests of its fundamental ideas. "It has therefore created a culture in which supporters believe the theory need not pass the same stringent tests as other theories to prove its rightness," he says.

Loeb does not necessarily think that inflation is wrong. But he thinks alternatives should be taken more seriously. "I have no disagreement with that," says Guth. "But we should avoid making false claims that inflation can't be evaluated by the scientific method. And I would also disagree with claims that any of the current alternatives to inflation have a comparable stature."

FROM BANG TO BOUNCE

One alternative is that the Universe didn't begin with a burst of vacuum-driven inflation but instead underwent a previous contraction phase. The Big Bang would therefore not have been a Big Bang but a Big Bounce. There are a number of possibilities, one of which is the 'cyclic Universe' posited by physicists Steinhardt and Neil Turok, in which the Universe undergoes repeated bounces, possibly an infinite number of them, and therefore has no beginning [see box, right]. Crucially, though, a long pre-Big Bang phase provides plenty ►



The cyclic universe builds on string theory, which views the fundamental building blocks of matter not as tiny point-like particles but as 'strings' of mass-energy vibrating in 10-dimensional space-time. In addition to 1-dimensional strings, the theory requires the existence of 2-, 3-, 4-... dimensional objects known as 'branes'. The idea has therefore arisen that our Universe may be a 3-dimensional island, or 3-brane, floating in the 10-dimensional space-time. In the cyclic scenario, our brane is not alone but collides with a second brane. Imagine the two branes – empty of matter – coming together like two slices of bread to

make a sandwich. As they pass through each other, their energy of motion is converted into the mass-energy of matter on each brane, which is created at a ferocious temperature. This is a big bang. Since the branes touch each other everywhere at once, the release of collisional energy is exactly the same at every point, so the temperature across each brane is automatically evened out. When matter on each brane has expanded and diluted to nothing the branes – think of them as being connected by a spring – pass through each other again, repeating the process. The result is an infinite series of big bangs.



ABOVE and ABOVE
RIGHT The BICEP2
experiment, currently
underway in the Antarctic,
is looking for signs of
inflation in the cosmic
background radiation

of time for properties of the Universe to equalise, just as a long time allows a bath of cold water to come to an even temperature after hot water is added.

The key thing is to find an observation capable of distinguishing between inflationary and bouncing scenarios. And Loeb and his Harvard colleagues, Dr Xingang Chen and Zhong-Zhi Xianyu, say they've found one. It involves the heat afterglow of the Big Bang – the cosmic background radiation.

The Standard Model of particle physics describes the fundamental 'fields' that make up our Universe. An electron is a

**“WITHOUT A QUANTUM THEORY
OF GRAVITY, WE CAN NEVER
REALLY BE SURE HOW OUR
UNIVERSE BEGAN”**



STEFFEN RICHTER/HARVARD UNIVERSITY, SCIENCE PHOTO LIBRARY

ripple in the ‘electron field’, a photon a ripple in the ‘electromagnetic field’ and so on. The Standard Model, however, is only an approximation of an as-yet-unknown deeper theory. But Loeb says it will contain new fields with new massive subatomic particles. These will oscillate in the early Universe, imprinting a telltale regularity on the temperature variations of the cosmic background radiation. “This ‘periodicity’ is potentially observable,” says Loeb. “And the crucial thing is that it’s different for a Universe that underwent an inflationary expansion and one that underwent a contraction.”

The largest temperature variations are set in place first in an expanding scenario but last in a contracting scenario. And since the size, or amplitude, of the temperature variations grows with time, it is possible to tell which scenario was first.

“I’m glad to see that two years after proclaiming that inflation can’t be evaluated using the scientific method, Loeb is working on the development of a test of inflation,” says Guth. “The proposal by Chen, Loeb and Xianyu, in my opinion, contains some very interesting physics.”

The new test is not the only possible test of inflation. An experiment at the South Pole called BICEP2 is currently looking for the imprint on the cosmic background radiation of ripples in space-time (gravitational waves), created in the violent turmoil of the early Universe. “If the imprint is found, it will prove inflation,” says Loeb. “But if the imprint is not found, it will be possible to find an inflationary model where the imprint is undetectable. This is what I mean about the theory being infinitely flexible and scientifically unfalsifiable.”

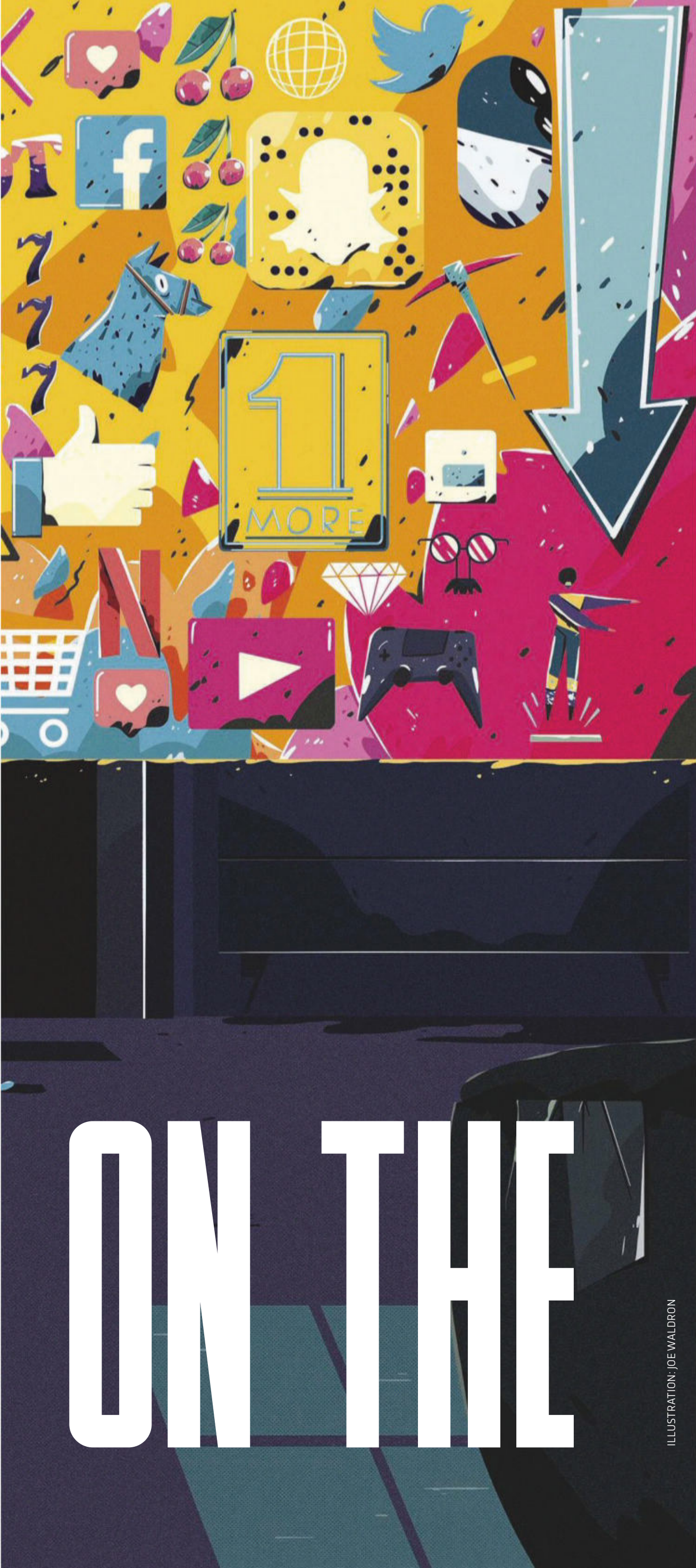
Loeb admits that the detailed physics of a cosmic bounce is as unknown as the detailed physics of inflation. But he says this is inevitable because of the state of our knowledge of fundamental science. The two towering achievements of 20th-Century physics are quantum theory (which describes the world of the very small) and Einstein’s theory of gravity (which describes the very large domain of the Universe). In the Big Bang, a very big Universe was very small and therefore it is necessary to unify quantum theory and Einstein’s theory of gravity in order to predict what went on. Such a unification has so far proved elusive. “The stark truth”, says Loeb, “is that, without a quantum theory of gravity, we can never really be sure how our Universe began.” **SF**

by **MARCUS CHOWN** (@maruschown)

Marcus is the author of *Infinity In the Palm of Your Hand: Fifty Wonders That Reveal An Extraordinary Universe* (£14.99, Michael O’Mara Books).



IS ADDICTION



RISE?

VIDEO GAMES, TV SERIES AND SOCIAL MEDIA. IT SEEMS THAT MANY OF US ARE HOOKED ON SOMETHING. BUT ARE THINGS AS BAD AS THEY APPEAR?

Words by **DR SUZI GAGE**

illustration by **JOE WALDRON**

If you, or people you know, are affected by addiction, visit bit.ly/addiction_support for information and support.



Listen to an episode of *Four Thought* about drug addiction, presented by Hanna Pickard.
bit.ly/four_thought

ON THE

ILLUSTRATION: JOE WALDRON

The media is full of reports of addiction to pornography, gambling, video games, phones and even the internet. Parents are concerned that they can't drag their kids away from their tablets, while on any bus journey you can see dozens of people mindlessly scrolling. But are we as hooked on these behaviours as the stories make out? And most importantly: are levels of addiction on the rise, as technological advances put these enjoyable temptations in our pockets? Certainly, data collected by government body the Gambling Commission suggests that problem gambling behaviours are on the rise, estimating in 2017 that approximately 430,000 individuals in the UK had a serious gambling problem, a rise of more than one-third over the previous three years. It's perhaps not surprising: whereas once you'd have to go down the betting shop or off to a bingo hall if you fancied a flutter, now you can simply download an app. ➤



“IF THERE’S NO HARM TO US OR TO OTHERS, WE SHOULD BE FREE TO CHOOSE HOW TO SPEND OUR TIME”

DEFINING ADDICTION

Addiction is a term that we hear all the time, but it’s a surprisingly tricky concept to pin down. Colloquially, we might say things like: “Oh, I downloaded this new game on my phone and I’m totally addicted to it”. But from a clinical perspective, we think of addiction as occurring when someone has found that their life – whether it’s their relationships with friends or family, their ability to perform their job, or something else – has been knocked off-kilter by a compulsion to perform a behaviour.

In the past, the perception has been that addiction only occurs due to regular heavy use of a substance, like tobacco, alcohol or an illegal drug. But a lot of what causes dependence to a drug is psychological rather than biological.

Prof Robert West, director of tobacco studies at UCL and editor-in-chief of the journal *Addiction*, defines addiction as “a psychological condition that involves repeated powerful motivation to engage in a behaviour that’s learnt through experience, and that has either actual or potential harmful consequences”. Under this definition, it is possible to be addicted to anything – not just substances – if it turns from a *want* for it to a *need* for it, and it puts a person at risk of harm.

Yet much like with substance use, the vast majority of people who play games online, watch pornography, or use the internet will not experience problems from doing so. Dr Henrietta Bowden-Jones, a consultant psychiatrist and researcher based at Imperial College London, highlights how little we know about the prevalence of behavioural addictions – in particular, gaming.

So how do we tell the difference between just really liking something – what we might colloquially call addiction – and a behaviour that is becoming problematic? For Bowden-Jones it’s about loss of control. She mentions a colleague of hers who regularly binge watches Netflix, for hours at a time. But his Netflix binging doesn’t impact his work, or his relationship – he is choosing to do it. And Bowden-Jones sees nothing wrong with this. “If there’s no harm to us or to others, we should be free to choose how to spend our time,” she says. It becomes a problem, however, when someone tells themselves they will stop at midnight, but finds they’re still watching when the sun rises, and starts missing work or school, or isolates themselves from friends or family. She also suggests that the joy from the behaviour reduces. “It’s not fun any more, it’s not pleasant, and it leaves them distressed,” she says of people she has treated for behavioural addiction.

If someone struggles to control their impulses, they might find

it harder to resist temptation, making them more vulnerable to addiction. An inability to limit themselves could make a person more likely to constantly reach for their phone, or place another bet when they know they should stop. All of this could lead to dependence. Addiction problems also seem to run in families, which might indicate the involvement of genetics. But genetic variants alone don't cause addiction, though they might tip the scales. West points out the importance of society and culture, highlighting smoking prevalence in China. "In China, 60 per cent of men smoke, and about 3 per cent of women," he says. "There's nothing different about those Chinese women than British women to make them less susceptible, it's just taboo [for women to smoke in China]". A person's support network, their upbringing, the level of deprivation in which they live and a host of other social and cultural factors will also strongly predict whether a person is at risk of developing addiction.

BODY AND BRAIN

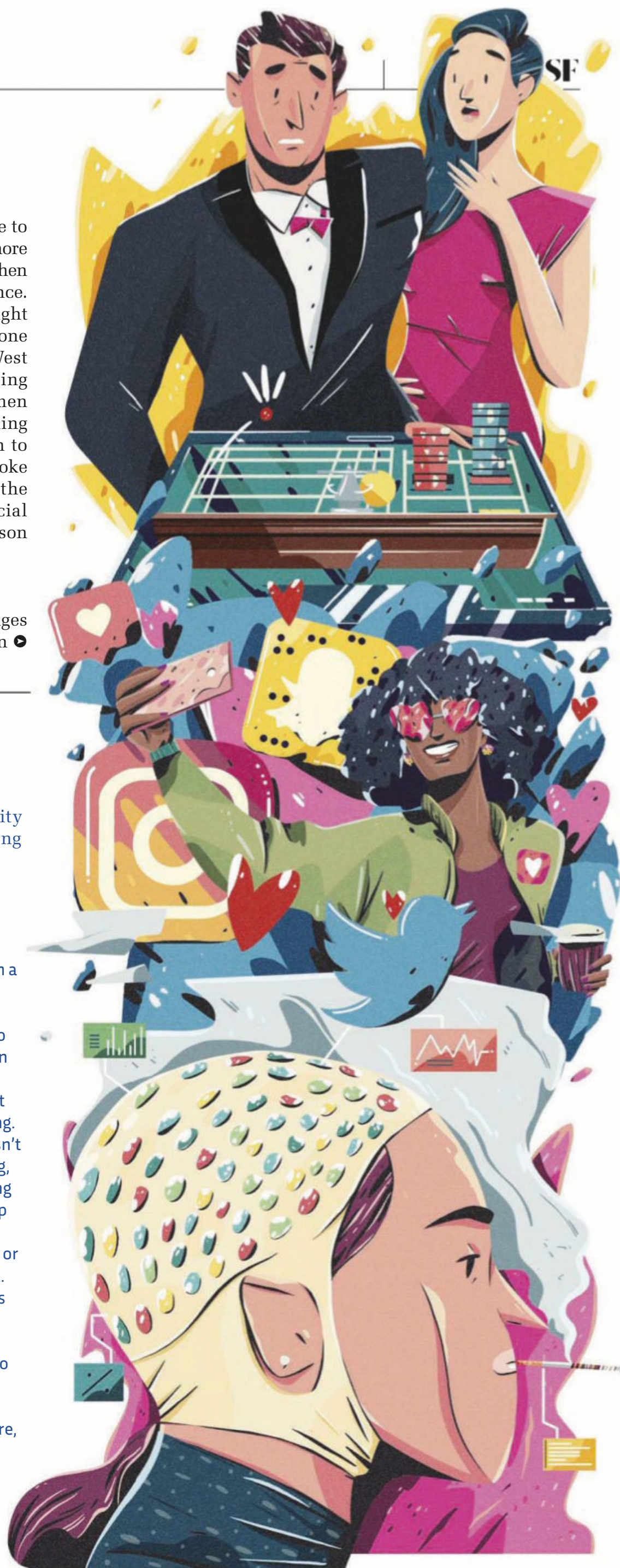
There's also the question of whether addiction leads to changes in the brain. The neurotransmitter dopamine has long been

HELLO, I'M AN EVERYTHING OHOLIC

Have you always blamed your chocolate habit and inability to stop smoking on your 'addictive personality'? According to science, there's no such thing...

It's a widely held belief that some people are just hardwired to be hooked. But is there actually any evidence for this? According to addiction expert Prof Robert West, there isn't. However, there *are* personality characteristics, like anxiety, depression and impulse control problems, that might make a person more vulnerable to addiction. He says this is an important distinction, because the term 'addictive personality' implies that if a person stops one addictive behaviour, they'll just start another, and that's not what happens. If a person has underlying risk factors for addiction, whether it's related to their mental health, their personality, or other factors such as a family history, then stopping one behaviour will not then make them immune to the risk of other addictions. But they won't be more at risk of another

addiction just because they overcame one. West points to research that investigated the impact of stopping smoking on a person's drinking behaviour. Studies have found that when people stop smoking, they also show a short-term reduction in alcohol consumption, which gradually returns to the level it was at prior to quitting smoking. But alcohol consumption doesn't increase after quitting smoking, and the same is true of smoking heaviness when people give up alcohol. "If anything, stopping one can be helpful in stopping or reducing the other," says West. Of course, there are exceptions and anecdotes of individuals who have given up one substance or behaviour, only to have another take over their lives. According to West, while the vulnerabilities are still there, there's no evidence that an addictive personality exists.



● implicated in addiction. But it's implicated in pleasure generally, from the feeling of winning on a scratchcard, to enjoying a delicious piece of chocolate cake. How taking pleasure from something can lead to dependence is less well understood, though there is some evidence that dopamine interacts with another neurotransmitter in the brain called glutamate, which can lead to a growing feeling of *needing* something, rather than *wanting* it. Over time, sensitisation to dopamine might develop, reducing the feeling of pleasure that something brings. While using substances like drugs or alcohol will directly alter brain chemistry – at least during intoxication – behaviours can also induce pleasure (and therefore dopamine) in much the same way, so the processes of developing addiction to a behaviour are likely to be broadly the same as for a substance.

In 2008, Bowden-Jones set up the National Problem Gambling Clinic. To date, this is the only NHS-funded treatment centre for people with problem gambling. Despite seeing some of the most severe cases of gambling addiction in the country in her clinic, she is keen to point out that the scale of the problem might not be as extreme as some would think. Despite lots of people

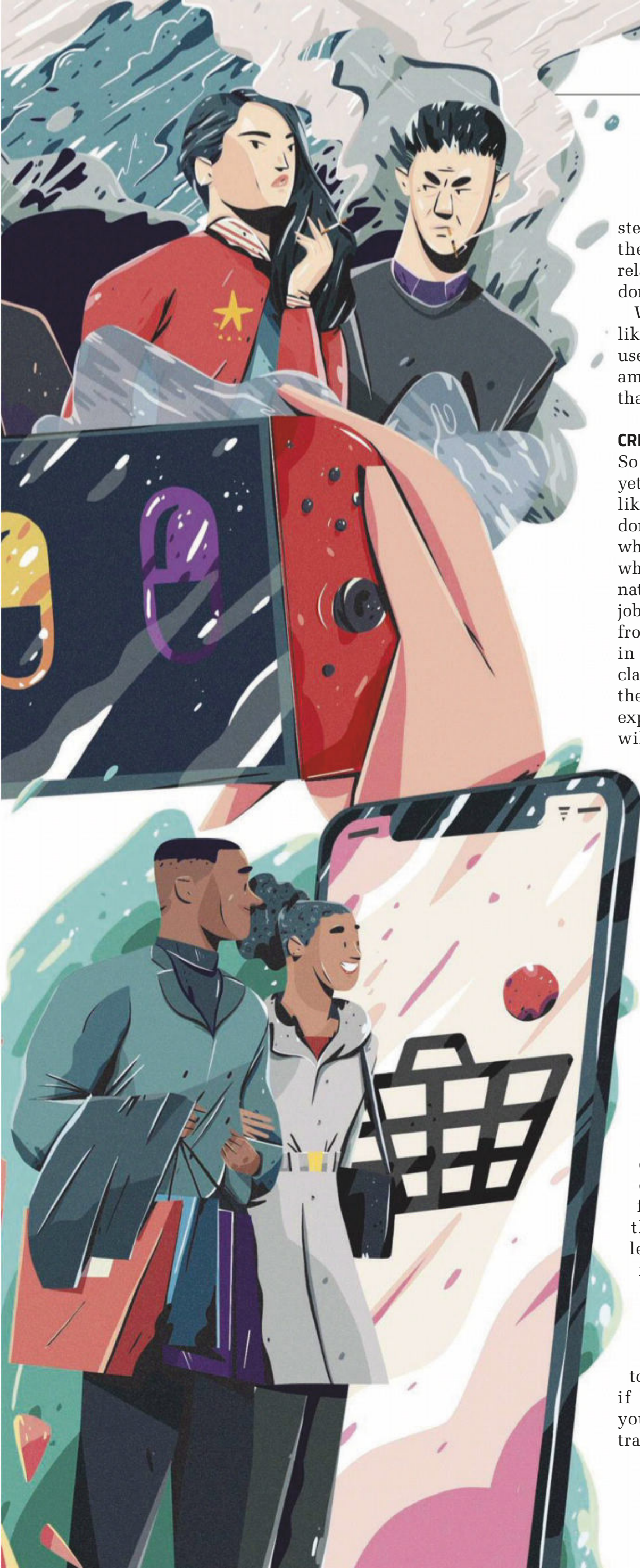
“SELF-CONTROL IS MUCH EASIER WHEN YOU SET FIXED BOUNDARIES THAN WHEN YOU LEAVE THE RULES MORE FLEXIBLE”

gambling and the pervasive nature of gambling advertising, problem gamblers make up less than 1 per cent of the population.

Yet she wonders whether there is something about how ubiquitous technology has become that increases risk. “The more you have availability, the more you uncover vulnerability,” she says. And there's concern among researchers from several different countries that online games and apps are taking inspiration from gambling to keep people playing, and paying. These include what are known as ‘loot boxes’. These are prizes, paid for with real money, where the contents are not known until they're purchased. Recent research has suggested purchase of these prizes is linked to higher levels of problematic gambling behaviour. And this link gets even stronger when the games employ another device used by the gambling industry – the near miss, showing people what they could have won alongside what they did win.

However, Bowden-Jones points out that technological advances have also improved support for some people with problematic gambling. Software now exists to block gambling-related websites across people's devices. Banking apps can allow a person to disable any ability to spend money on gambling, discreetly, by just toggling a switch. She believes that this is a big





step forward – historically people were encouraged to hand their finances to their partners. This can put pressure on relationships and there is strong evidence to show it can increase domestic violence.

While public attention is turning to behavioural addictions like gambling and gaming, it's worth highlighting that substance use, particularly smoking and drinking, seems to be going down among young people in the UK. West thinks that it's possible that they might be moving from one risky behaviour to another.

CREATE BOUNDARIES

So is addiction on the rise? It's hard to tell, partly because as yet there aren't standardised measures by which to assess things like problematic gaming, and large-scale surveys have not been done. But just because we might see people glued to their phones while they're on buses or trains, while they're socialising, or even while walking down the street, it doesn't mean we've become a nation who are addicted to the internet. We aren't all losing our jobs because we are playing *Angry Birds*, or becoming isolated from those closest to us because we're on Twitter. Nonetheless, in 2018 the World Health Organization announced that it was classifying gaming disorder as a mental health condition, a decision they based on a review of the evidence and after discussion with experts. However, some researchers worry that this classification will lead to overdiagnosis and a pathologising of gaming. The

NHS does not offer treatment for gaming disorder, and a pilot treatment clinic has been delayed. It's clear that we know very little about how many people have gaming disorder, and it's likely that the vast majority of people who play games do so with no detriment to their health whatsoever.

Having said that, for those who are worried, it is possible to spot the warning signs of a pleasurable activity becoming a compulsion, either in yourself or in those around you. Bowden-Jones highlights behaviours such as isolation, a loss of interest in previously enjoyed activities, removing oneself from previously enjoyable family moments, or a worsening of school grades as being potential causes for concern. Though some of these sound a little like normal teenage behaviour, Bowden-Jones says that it's the negative consequences that you need to look out for, particularly when it comes to isolation. "People stop having meals with parents or peers. They stop going to school," she says.

West has some final words of advice for those individuals who are trying to reduce their need for a behaviour. "Self-control is much easier when you set fixed boundaries than when you leave the rules more flexible," he explains. Be strict with yourself and don't allow your boundaries to slide, then even if you do slip up, you can get back on track. **SF**

by **DR SUZI GAGE** (@soozaphone)

Suzi is a Wellcome Trust Engagement Fellow and lecturer at the University of Liverpool. She makes the award winning podcast Say Why To Drugs. Her first book will be published in 2020.

DISCOVER MORE



To listen to an episode of Inside Science about the science of addiction, visit the BBC Sounds website [bit.ly/bbc_sounds_addiction](https://www.bbc.com/sounds/addiction)

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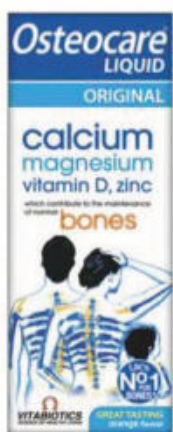
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Q & A

ALL YOUR QUESTIONS ANSWERED

GETTY IMAGES

THIS ISSUE'S EXPERTS

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Flying squirrels are adorable – but inaccurately named



ADAM KING, HUDDERSFIELD

ARE THERE ANY LIVING THINGS THAT CAN FLY WITHOUT WINGS?

Depending on how strict you want to be, you might say that flying squirrels, flying frogs and flying lizards all count. But these are really only gliding or parachuting, and the various flaps of skin stretched between their legs, toes or ribs are also suspiciously similar to wings.

However, the flying snakes of the genus *Chrysopelea* are in a different league. They can flatten their body so that it's twice as wide as normal, and curved inward on the underside. When they leap from a tree, they don't simply glide passively. Instead, they undulate their body sideways in a way that actually generates lift over their wing-shaped body. Flying snakes can travel up to 100m with this method – further than the other gliding animals.

Even more impressive are the various species of spider that can spin silk into thin air and use it like a kite to transport themselves. Most land a few metres away, but they can be carried up into the jet stream and travel for thousands of kilometres. **LV**

BENJAMIN MATTHEWS, CREWE

WHEN I'M ILL, SHOULD I JUST LET MY FEVER BURN ITSELF OUT?

Fever is a classic sign of a viral infection like the flu. There's nothing for it but to rest, drink plenty of water and take paracetamol to deal with the aches and high temperature. At least, that's the standard advice, but there's growing evidence that it might actually hinder recovery.

That's because the fever isn't caused by the virus itself, but by the body's own infection-fighting system. First recognised by physicians over 2,000 years ago, the benefits of having a fever (a temperature of at least 38°C) have been confirmed by the latest immune system research. This has shown that viruses struggle to thrive at high temperatures, while our immune system works better. A host of other organisms from

mammals and birds to amphibians and reptiles have also evolved immune systems that increase body temperature to fight infection. So while lowering our temperature might make us feel more comfortable, it could do more harm than good.

So why doesn't the standard advice reflect this? Part of the reason is the principle that the body must stay within a strict temperature range to be healthy. So if the body struggles to do this, the argument runs, it must be given help. Yet there's been little research into whether fever-busting drugs

like paracetamol really do help patients, and among the studies that have been carried out, some have found hints that it can make them worse. Another reason fevers are seen as bad is concern that they can run out of control. With some conditions, like heatstroke and some kinds of brain damage, that's a proven risk. Even so, for conditions like flu, the standard advice is starting to look questionable.

This said, the story is still not complete, so in the meantime, if you have a fever, we recommend following the current NHS guidelines of treating it with medication. **RM**



RICHARD FOSTER-FLETCHER, VIA EMAIL

COULD WE EVER MOVE A PLANET INTO A MORE HABITABLE ORBIT?

Although it's theoretically possible to change the orbit of a planet, it's probably completely impractical. Moving Mars, for example, to an orbit closer to the Sun would require decreasing its kinetic energy enormously – perhaps by shunting large asteroids into close encounters with it. This would likely take many centuries or millennia to complete, and would require huge amounts of energy. If the aim is to aid in the terraforming of Mars, there would be far cheaper, quicker and more effective ways to do it. **AGu**

CAREL LUCAS, PERTH, AUSTRALIA

HOW CAN MY CAT KNOW THAT A THUNDERSTORM IS ON ITS WAY AN HOUR BEFORE I DO?

Cats and many other animals are more sensitive than humans to sounds, smells and changes in atmospheric pressure, and their heightened senses can allow them to pick up hints that a storm is coming well before their owners catch wind of it.

Just before a storm, your cat's inner ears may detect the sudden fall in atmospheric

pressure, and she may have learned to associate this with an impending storm. If a storm is already raging in the distance, she may be able to perceive the faint rumble of thunder. Likewise, she may be able to smell the incoming rain, or the characteristic whiff of ozone gas, which is often created by lightning and has a sharp, metallic odour. **AFC**



EXISTENTIAL FEAR OF THE MONTH...

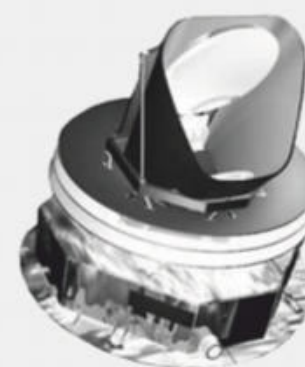
...WE'RE RUNNING OUT OF COFFEE

Coffee could soon be extinct – or at least the wild varieties of the coffee plant could be. The first full assessment of the threats to the 124 different species of wild coffee was published earlier this year by scientists at Kew Gardens, who found that 60 per cent of species are threatened with extinction due to climate change, deforestation, pests and diseases. The proportion of coffee species at risk is three times the figure for plants generally, which suggests that coffee is an especially vulnerable plant.

Cultivated coffee beans are all of two species: either arabica (*Coffea arabica*) or robusta (*Coffea canephora*). Although the new study didn't look directly at the threats to these two species, it's likely that the same environmental pressures that apply

to wild coffee will affect commercial plantations as well. Even more worryingly, coffee growers rely on wild coffee plants to crossbreed them with commercial varieties and create new resistances to insects, disease and changing climates. If we lose the genetic diversity present in the wild, commercial growers may not be able to protect their crops against the sudden outbreak of new pests – such as the potato blight that destroyed the Irish potato harvest in the 19th Century.

Like many tropical plants, coffee seeds don't survive the freeze-drying process used in most seed banks. So scientists will need to use more advanced techniques to preserve the DNA of the wild plants before they are lost entirely. *LV*



ESA's Planck observatory studied the CMB from 2009 to 2013

THEODORE, HERNE HILL

IF WE MADE A POWERFUL ENOUGH TELESCOPE, WOULD WE THEORETICALLY BE ABLE TO SEE THE LIGHT FROM THE BIG BANG?

Astronomers already *can* see the light from the Big Bang, or at least the first light formed after the Big Bang occurred. It is called the 'cosmic microwave background' (CMB). The first photons were created around 10 seconds after the Big Bang, but were initially unable to travel because they were constantly interacting with subatomic particles. It was only after those subatomic particles combined to form atoms, about 378,000 years after the Big Bang, that the photons were able to propagate through the Universe. The CMB is the relic radiation from that time.

Since then, the Universe has cooled and expanded. This has 'redshifted' the CMB light so that today it appears as a background glow which is brightest in the microwave region of the electromagnetic spectrum. Using radio telescopes such as the Planck satellite, astronomers now have high-resolution maps of the CMB, which encode important details of the Universe's early history. *AGu*

76 million

The number of litres of Agent Orange dropped on Vietnam by US troops, 1962-71. A new study shows toxins are still entering the food chain.

OLD WIVES' TALES...

RED SKY AT NIGHT, SHEPHERD'S DELIGHT

This saying can be traced back as far as the Bible – and a red sunset does typically presage clear skies the following day. However, this only holds true in regions where weather systems mostly travel from west to east, which includes most mid-latitude areas such as the UK.

During the daytime, the sky appears blue because dust and particles in the atmosphere mostly scatter the blue portion of sunlight. When the Sun is low on the horizon, however, the sunlight passes through more air than when it's higher in the sky. This means that by the time the light reaches us, most of the blue light has been scattered away from our line of sight – leaving the oranges and reds. A particularly red sky results from high atmospheric pressure, where particles are more highly concentrated and more blue light is scattered. A red sunset therefore usually means that there's an area of high pressure (which is associated with clear skies) approaching from the west.

If, on the other hand, you observe a red sunrise (ie, in the east), it suggests that a high pressure area has already passed overhead and is moving away. Lower pressure air will soon take its place, bringing rain or even storms – hence the phrase's companion, "red sky at morning, shepherd's warning". **AFC**



TOBY GRAHAM, SHREWSBURY

WHY DO CARS LOSE HORSEPOWER AS THEY AGE?

Things tend to get dirty and worn over time. Air filters and exhausts can clog up, blocking airflow to and from the engine; fuel injectors and spark plugs can get mucky, causing less efficient firing; and fuel pumps can wear out and no longer pump fuel so well. Meanwhile, combustion byproducts can form deposits, stopping engine valves closing, reducing pressure generated by the burning fuel and causing backfires. More seriously, inside the engine the piston rings can wear down, reducing the pressure in the cylinders and lowering the power output. Keep your car serviced regularly, though, and a modern engine should only lose a few per cent of horsepower over hundreds of thousands of miles. **PB**

CHE LOWENSTEIN, HASSOCKS

WHY DO I HAVE MORE VIVID DREAMS WHEN SLEEPING IN A BED OTHER THAN MY OWN?

It's well known that our sleep can suffer on the first night in a new environment. Sleep scientists noticed this decades ago when they started studying people in sleep labs, dubbing it the 'first-night effect'. One recent study found that the left side of the brain experiences lighter sleep than the right side during the first night. This may be an evolutionary mechanism to keep us alert to potential dangers in unfamiliar surroundings. We're more likely to wake up during the first night, and because we tend to remember our dreams better when we wake up a lot, this is probably why your dreams feel more vivid than usual. **AGr**



MARK BUCKMASTER,
VIA EMAIL

WHAT CAUSES 'PINE MOUTH'?

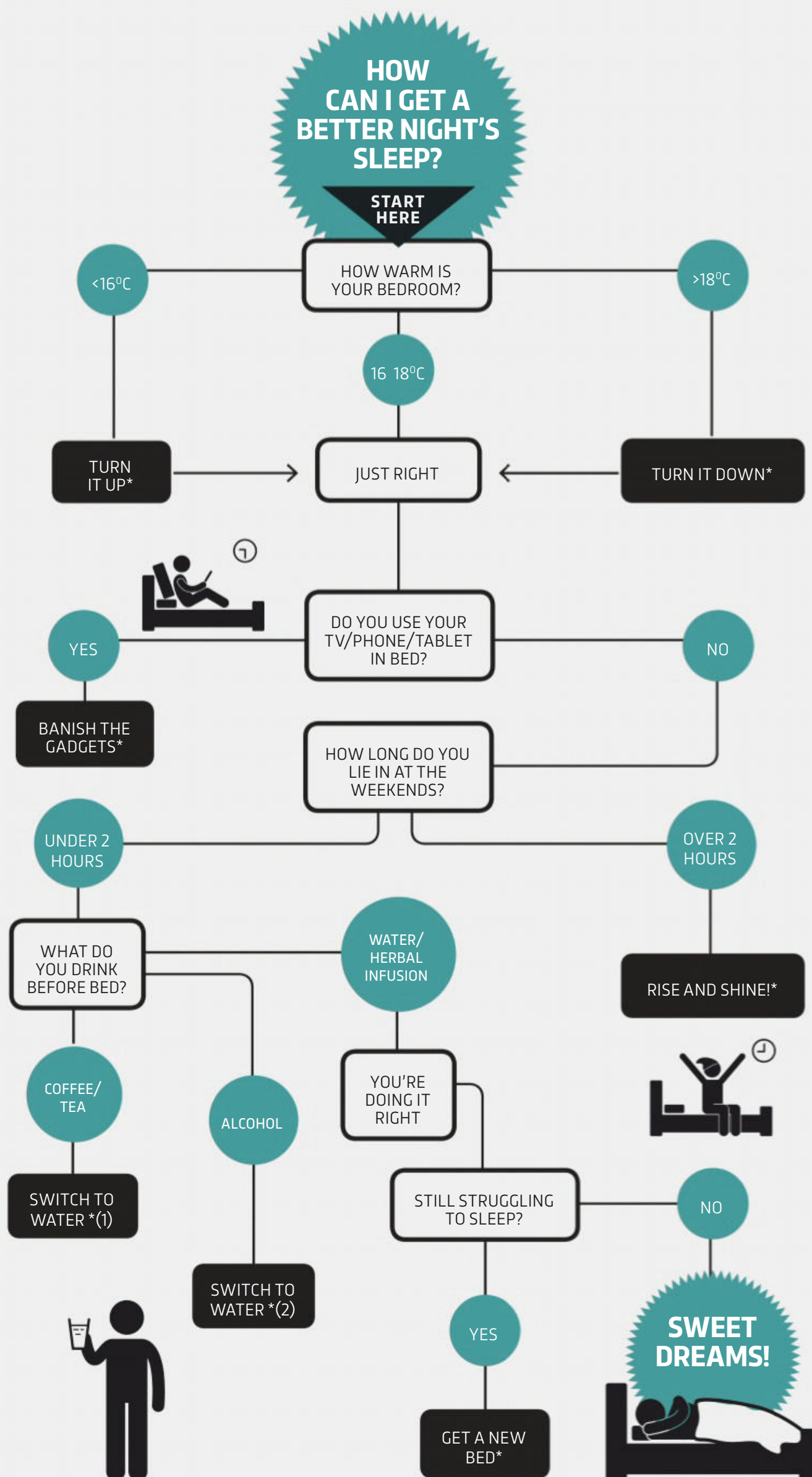
A few days after eating pine nuts, some people get a bitter, metallic taste in their mouth, which can last for weeks. Research has linked the taste to a species of pine nut from China (*Pinus armandii*), but scientists are still trying to figure out what causes the strange taste and why only some people are affected. The good news is that while the symptoms are unpleasant, there are no long-term negative health consequences. **KA**

CHRIS McMULLON,
BARNHAM

ARE THERE ANY ORGANISMS WHICH HUMANS PARASITISE?

A parasite is an organism that lives in or on another organism, getting food from and causing damage to its host. Humans have many parasites, including hookworms, head lice and *Plasmodium* (single-celled organisms that cause malaria). But we aren't parasites ourselves because we don't live in, or on, any other species. **LV**

ALGORITHM YOUR LIFE



TURN IT UP

If you're too cold, you'll be shivering to generate heat, which uses energy and keeps you in a half-asleep state.

TURN IT DOWN

If you're too hot, you'll be tossing and turning.

BANISH THE GADGETS!

The light from your mobile devices (or TV) contains blue wavelengths that suppress your body's production of melatonin – the hormone that regulates sleep.

SWITCH TO WATER (1)

It takes between three and five hours for your body to reduce the caffeine in your bloodstream by 50 per cent, at which point you might still be feeling the effects. So avoid caffeinated drinks from mid-afternoon onwards.

SWITCH TO WATER (2)

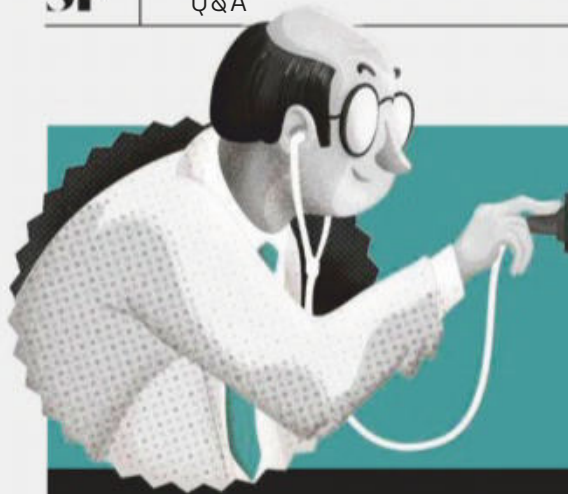
While alcohol makes it easier to drop off to sleep, it also suppresses the production of melatonin (the sleep hormone), meaning that you're more likely to wake in the middle of the night.

RISE AND SHINE!

Most people accumulate around five hours of sleep debt during the week. But it only takes one and a half hours extra at the weekend to make up for this, because your body automatically spends more time in deep sleep to catch up. Sleeping in for longer risks disrupting your natural sleep cycle.

GET A NEW BED

An uncomfortable bed or mattress can rob you of quality sleep. The national bed federation offers buying advice (bedfed.org.uk).



DEAR DOCTOR...

DELICATE ISSUES DEALT WITH
BY SCIENCE FOCUS EXPERTS

I HATE VEGETABLES BUT LOVE CAKE. CAN CARROT CAKE GIVE ME ONE OF MY FIVE-A-DAY?

A popular recipe on the BBC Food site requires 525g of grated carrots for a 26cm-wide cake. NHS guidelines state that three heaped tablespoons of cooked carrots counts as a portion, which is about 60g. This suggests that a whole cake contains more than eight portions of carrots, so a largish slice ought to count as one of your five-a-day. We can argue about whether the carrots lose some volume during the cooking process, but you could easily compensate by just eating another slice!

The problem is that each slice also contains more than 900 calories and 50g of fat. If you tried to get all your vegetables from carrot cake, courgette cake and so on, you would be eating 4,500 calories a day and almost four times the recommended amount of fat. *LV*



BABY SHARK IS CONSTANTLY STUCK IN MY HEAD AND IT'S DRIVING ME CRAZY. HOW CAN I GET RID OF IT?

You could try chewing some gum – a few years ago, psychologists showed that this reduced volunteers' susceptibility to earworms, the theory being that chewing somehow hijacks the brain processes that are involved in 'subvocalisations' (singing or speaking in your head).

Another approach is to engage your mind with a task, such as a crossword or number puzzle, that is of just enough difficulty that your mind doesn't start to wander. The idea is to use up your cognitive resources so that your brain doesn't have the capacity to start playing its own music. Beware, though: if the task you take on is too easy or tricky, your mind will wander again, and the song will likely resume.

A final approach is to engage with

the earworm – one theory suggests that earworms get stuck because they are mere snippets and our brains don't like unfinished business. Listen to *Baby Shark* all the way through and, fingers crossed, you might find it goes away. *CJ*



I JUST BOUGHT A LOVELY NEW CAR, SO WHY IS THE SMELL OF IT MAKING ME FEEL SICK?

Many people enjoy that straight-out-of-the-showroom smell, but it's also not unheard of for it to prompt feelings of nausea. The cause is likely to be the so-called volatile organic compounds (VOCs) leeching out of the fabric, plastics and adhesives used inside the car. Studies by the

Ecology Center in Michigan, USA have found over 200 chemicals in car interiors, including the sickly-sweet, toxic hydrocarbons benzene and toluene. The problem is worst in new cars bought during the summer, when the materials are fresh and can get very hot. So it's

a good idea to keep the interior well-ventilated when driving, and park in the shade.

Fortunately, most of these volatile chemicals fade over time. If you still feel sick, then maybe it's not the car's smell that's to blame, but the thought of keeping up the repayments... *RM*



ALEX MORAN, DUBLIN

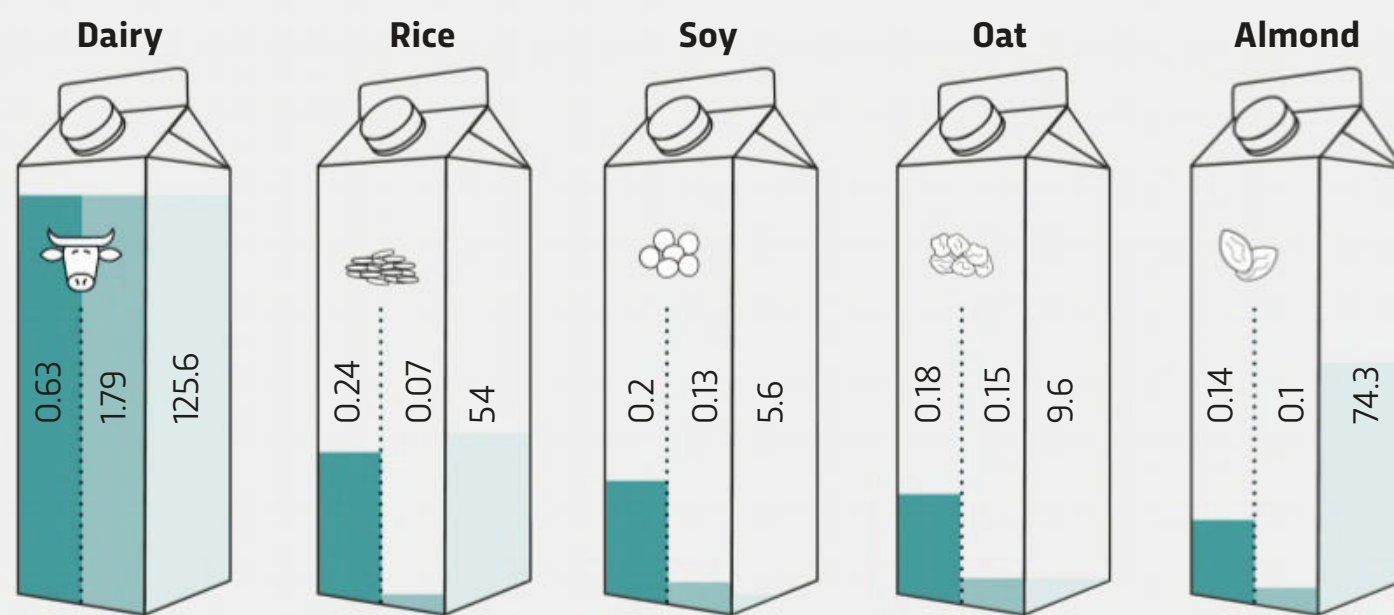
ARE THERE ANY ANIMALS THAT PREPARE OR COOK THEIR FOOD?

We're the only animals who cook our food, but others certainly join us in the prepping department. For example, adult bigheaded ants place food onto the bellies of their larvae for them to spit enzymes onto, resulting in a more easily digestible meal. In the bird world, shrikes (also called butcher birds) impale poisonous lubber grasshoppers on thorns for up to two days to allow time for the toxins to degrade before tucking in. Capuchin monkeys leave ripe palm nuts to dry in the Sun so that they can more easily crack the tough shells, while Japanese macaques have been known to wash potatoes, fed to them by researchers, before seasoning them in salt water! *AGu*

LIBBY CHAPMAN, NOTTINGHAM

WHICH VEGAN MILK IS BEST FOR THE ENVIRONMENT?

All of the non-dairy milks are much better for the environment than cow's milk. They use less land, less water and generate lower amounts of greenhouse gases. The milk with the lowest greenhouse gas emissions is almond milk, because the trees lock up a lot of CO₂ as they grow. However, it does require the most water to produce of the vegan milks. Soy milk uses the least water with only slightly higher emissions. **LV**



ENVIRONMENTAL IMPACT OF ONE GLASS (200ML) OF DIFFERENT MILKS

= Emissions (kg)

= Land use (square metre)

= Water (litre)

SOPHIE PARKS, LONDON

IS THERE A CURE FOR HYPOCHONDRIA?

Psychiatry ditched the term 'hypochondria' a few years ago as it was considered too pejorative, and replaced it with two related diagnoses: 'somatic symptom disorder' (distress due to bodily symptoms that can't be attributed to a medical condition) and 'illness anxiety disorder' (extreme anxiety about the possibility of having a serious illness, or developing one). There is no 'cure' for either condition, but both are considered treatable, mainly through psychotherapeutic techniques such as CBT (cognitive behavioural therapy), which aim to help the patient to relax and not to catastrophise when interpreting bodily sensations. **CJ**

NATURE'S WEIRDEST CREATURES...

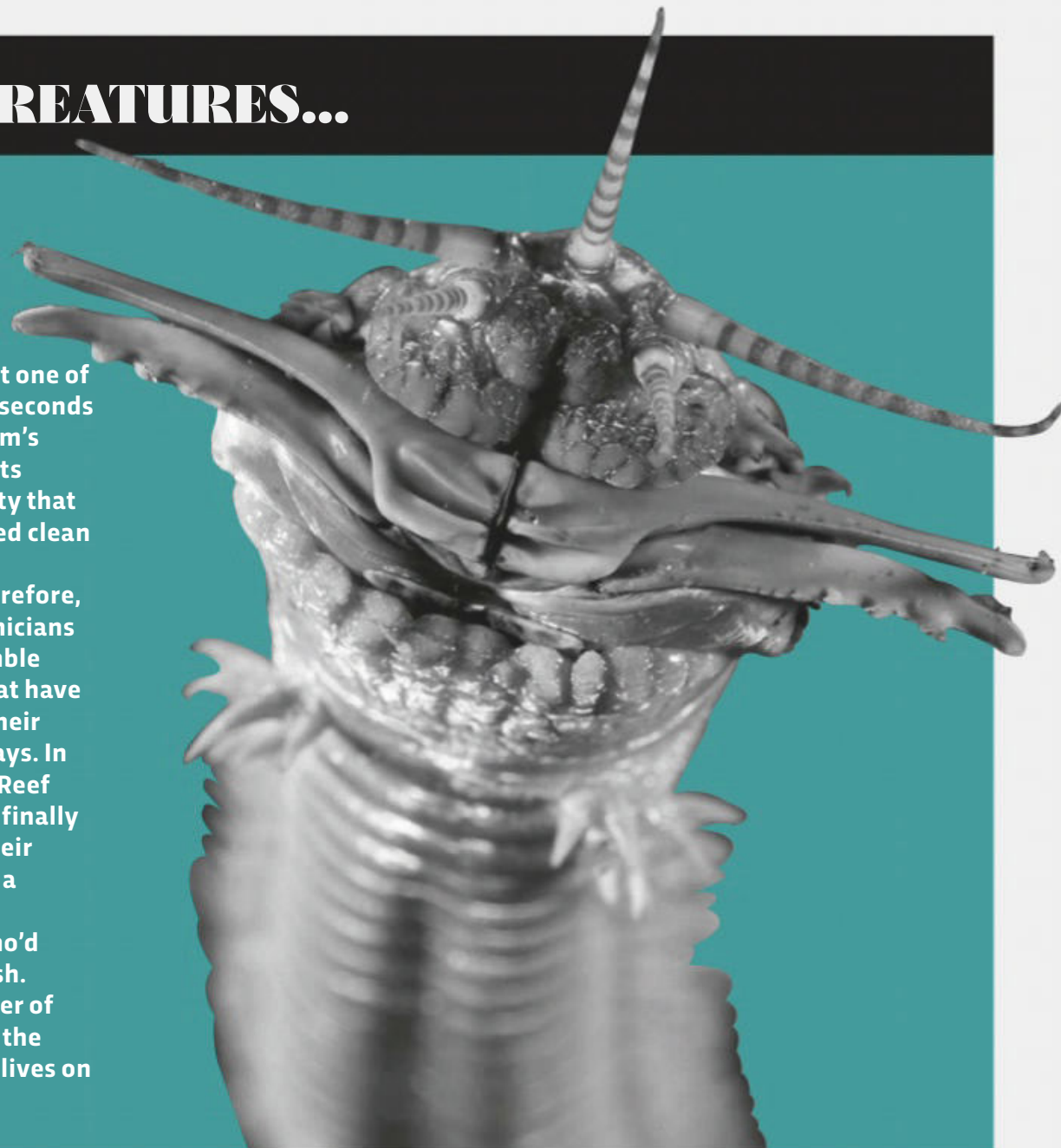
THE BOBBIT WORM

Readers of a certain age will remember the story of Mrs Lorena Bobbitt, who in 1993 made world news for taking a kitchen implement to her abusive husband's private parts. The report remained in the public consciousness for a number of years, which explains why in 1996 a lowly and largely overlooked ocean worm was finally bequeathed a common name – the bobbit worm (*Eunice aphroditois*).

The bobbit worm is a worm, weaponised. Found in warmer oceans around the world, it buries itself into sediment, leaving only its mouth exposed with its huge, scissor-like jaws open wide. Five antennae protruding from its head act like tripwires. If a fish should

accidentally brush past one of them, it has mere milliseconds to flee. The bobbit worm's razor-sharp mouthparts strike with such velocity that prey is sometimes sliced clean in two.

Spare a thought, therefore, for the aquarium technicians who occasionally stumble upon bobbit worms that have accidentally entered their collections as stowaways. In 2008, staff at the Blue Reef Aquarium in Newquay finally managed to remove their resident bobbit worm, a 1.2-metre specimen (nicknamed Barry), who'd been terrorising the fish. Today, Barry is no longer of this world. But he, and the species he represents, lives on in our nightmares. **JH**





CHRIS McMULLON, BARNHAM, WEST SUSSEX

WHAT'S THE OLDEST INVENTION THAT WE STILL USE TODAY?

We tend to think of ‘inventions’ as problem-solving ideas dreamt up by humans. But there’s evidence that we’re still benefiting from inventions consciously made by pre-human species. Certain types of crow have proved capable of making simple tools like hooks, and are suspected to have

done so for several million years, long before we arrived on the scene. Meanwhile, great apes – which include chimpanzees, gorillas and ourselves – are unique in creating a safe place to sleep each day, suggesting that beds and bed-making date back even further. **RM**

QUESTION OF THE MONTH

OLIVER NEELY,
FOLKESTONE

ARE ALL THE WORLD'S OCEANS AT THE SAME LEVEL?

Mean sea level (MSL) is widely used as the standard reference for the altitude of towns, mountains and aircraft. That’s because once the effect of tides and waves has been averaged out, sea level depends on just two forces: the strength of gravity and the effect of the Earth’s spin – and these depend on the distance from that

ultimate reference point, Earth’s centre. But while their surface provides a handy reference point, the oceans themselves are not all at the same height above the Earth’s centre. As the strength of the force generated by the Earth’s spin is strongest at the equator, the MSL bulges outward there,

putting it further from the centre of the Earth than at the poles. Differences in the Earth’s density also affect the strength of gravity, causing MSL variations of as much as 100 metres. MSL is also changing over time, largely through global warming causing seawater to expand and land ice to melt. **RM**

WINNER

Oliver wins a pair of Plantronics BackBeat FIT 3100 true wireless waterproof earbuds. Enjoy five hours of uninterrupted wireless listening, with the rechargeable storage case holding an additional 10 hours of charge. Download the BackBeat app to customise how you listen. plantronics.com



PHOEBE, LONDON

WHY ARE MOST MURDERS, RAPES AND VIOLENT CRIMES COMMITTED BY MEN?

The answer depends somewhat on who you ask. Sociologists will tell you that the tendency for men to be more violent than women is a result of traditional gender roles, such that in many cultures boys are raised to believe it’s important for them to be dominant and competitive, while girls are raised to be more nurturing and gentle. Evolutionary psychologists, however, would say that it has more to do with our evolved sex differences and the fact that males have historically competed for status and access to females.

A recent cross-cultural study using data from 63 countries around the world showed that male teenagers were nearly three times more likely to have engaged in fighting over the previous year than female teenagers. This difference was actually greater in cultures with more gender equality (ie, where traditional gender roles are not such an influence), so this provides support for the evolutionary explanation. **LV**



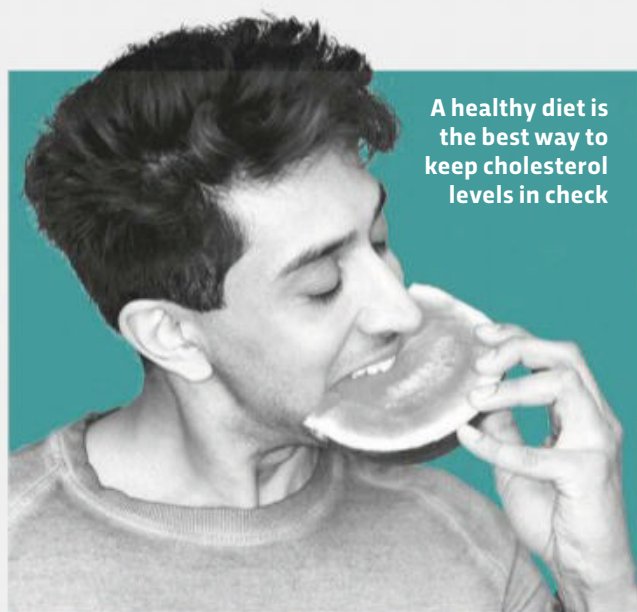
CONVICTED HOMICIDE SUSPECTS



94% male



6% female



A healthy diet is the best way to keep cholesterol levels in check

SIMON BARTLETT, VIA EMAIL

DOES SUNLIGHT REDUCE CHOLESTEROL?

When it's exposed to sunlight, our skin makes vitamin D. One theory is that because cholesterol is used in vitamin D synthesis, levels of cholesterol will reduce as more vitamin D is made. One study showed that doing outdoor activities such as gardening in the summer did indeed reduce cholesterol levels in the blood. This did not occur during winter. However, the reduction of cholesterol is so small that there would not be any meaningful health benefit.

So if sunlight isn't the solution, why not adopt a healthy Mediterranean diet? There is good evidence that this reduces the risk of heart disease by lowering the 'bad' type of cholesterol, responsible for clogging up our arteries. Eating more vegetables, fruits, nuts and olive oil could bring some sunshine into your diet! **KA**

5

Earth masses is the speculative mass of Planet Nine, the hypothetical planet that may or may not lie beyond the Kuiper Belt, according to the latest models.

ROB FRENCH, SHEFFIELD

HOW DO DINOSAUR FOOTPRINTS GET FOSSILISED?

Last December, over 80 dinosaur footprints were revealed at a site in East Sussex. They had survived for over 100 million years – and bear witness to the huge amount of luck involved in creating such fossils.

First, the creatures must step through sediment that is pliable enough to record their footprints, but not so pliable it gets washed away before being protected by fresh sediment. Each footprint then has three chances to become a fossil: as the original impression (the 'true track'), as its fainter impression in the underlying layers (the 'undertrack'), or by new sediment filling in the original impression (the 'natural cast') and hardening. Either way, as the layers of sediment build up, the pressure turns them to rock which – given yet more luck – will preserve the print intact for aeons. **RM**



WHAT CONNECTS

UNICORNS AND SUBMARINES?



Today, the unicorn is a famous mythical beast. Back in the 5th Century BC, though, Greek scholars wrote about the unicorn as an exotic, but very real animal that lived in India.



Early reports of unicorns were probably describing rhinos. But in the Middle Ages, long, thin, spiral 'unicorn horns' sold at great prices for use in magic and medicine. These were actually narwhal tusks.



Narwhals are a kind of toothed whale that grows to around 5m long. But in *Twenty Thousand Leagues Under the Sea*, the author Jules Verne imagined a narwhal 20 times larger that could sink ships.



Verne's novel featured a submarine called the *Nautilus*. This anticipated features that were only added to real subs much later, including hydroplanes to control diving angle, and battery-driven motors.

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RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH



1. Get bamboozled

Magicians exploit our psychology to deceive us, using bias and suggestion to affect our senses and tamper with our decisions. Learn how they do it at this exhibition.

Smoke and Mirrors
Wellcome Collection, London
11 April - 15 September 2019

2. Clever coffee

Coffee expert Mat North fed our editorial assistant a coffee made in one of these during our Troubleshoot interview, and it was so good we've now got one in the office.

Clever Coffee Dripper
£20
Find out more on p100

3. Save the sharks

Sharkwater Extinction documents Rob Stewart's mission to protect sharks, and was completed posthumously after his death in a diving accident during the final stages of filming.

Sharkwater Extinction
In cinemas 22 March 2019
sharkwater.com

4. Google gaming

Google's new gaming platform will use their acres of servers to offer high-end games, without a pricey PC or console. We don't know how much it'll cost, or when it'll be out.

Google Stadia
store.google.com/magazine/stadia

5. Explore ethics

Deborah Bowman, a professor of medical ethics, explores how her views on patient autonomy, communication and honesty changed when she became a cancer patient.

Patient Undone
BBC Radio 4, 16 April, 11am
Find out more on p96

6. Enjoy invention

Google Arts & Culture's newest online exhibition is the largest ever. It celebrates the inventions that have shaped society, from the first stone tools to jet propulsion.

artsandculture.google.com/project/once-upon-a-try
Find out more on p99

BBC, NASA, GETTY IMAGES



You can explore Robert Falcon Scott's Antarctic hut on Google Street View p99

800+

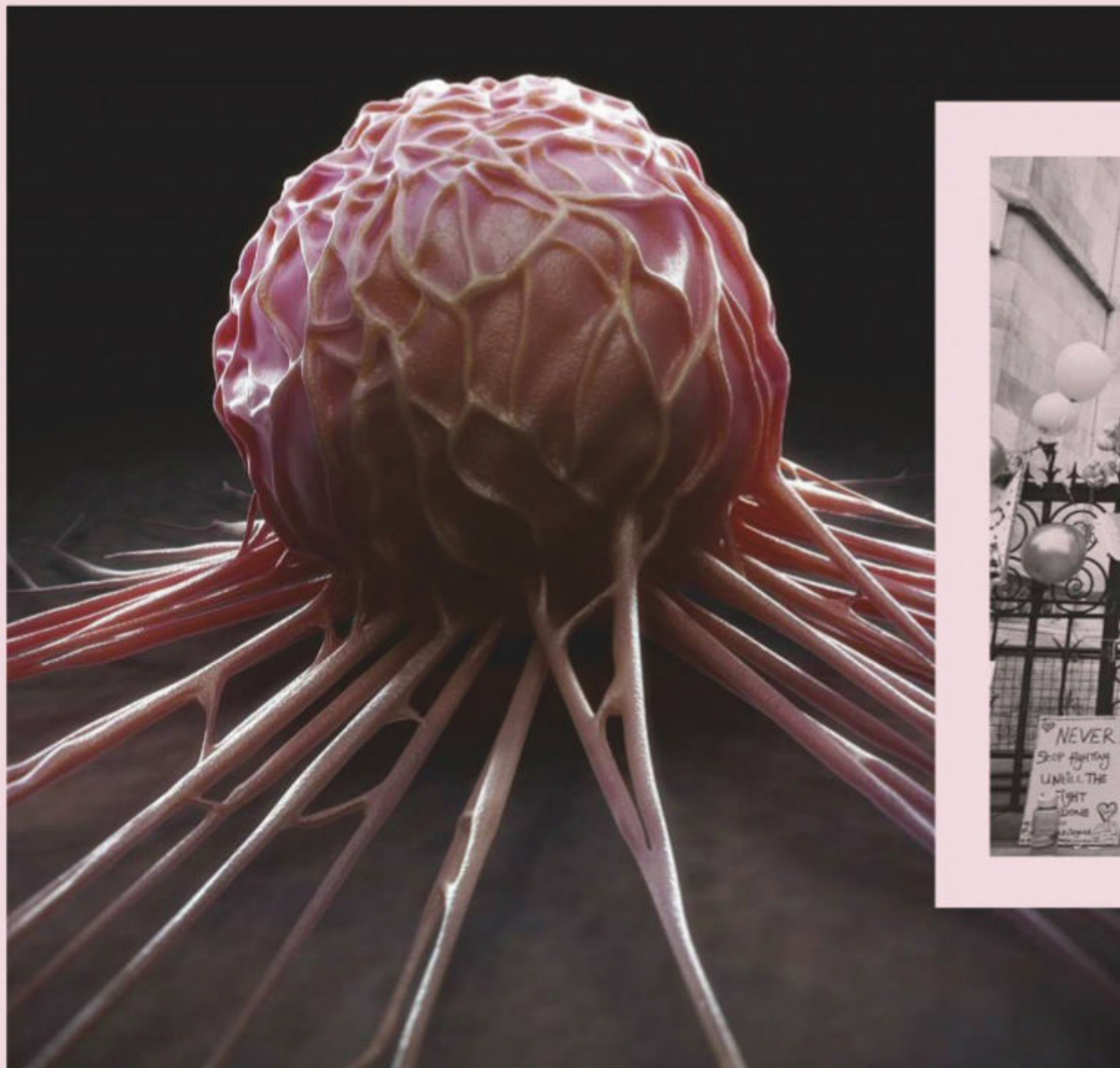
800+ possible flavour and aroma compounds can be produced by the Maillard reaction, where amino acids and sugars react during the coffee roasting process p101



Profile

EXPLORING ETHICS

**DR DEBORAH BOWMAN
SPENT MORE THAN 20
YEARS RESEARCHING
MEDICAL ETHICS,
BUT A 2017 BREAST
CANCER DIAGNOSIS
MADE HER RECONSIDER
EVERYTHING**



“There was another bit of me that was frightened, overwhelmed, and emotional ... I just wanted to stick my hands over my ears”

WHAT'S YOUR SPECIALITY?

I am a specialist in medical ethics. I work on wards and in clinics as well as doing research and teaching. When there's a moral question about what a clinician might do, or about what a patient wants, people come to me. High-profile cases include the Charlie Gard case, where the parents disagreed with the clinical team about the care for their very sick child. I wasn't involved in that, but it's an example of what people in my field do.

WHAT'S THE RADIO 4 PROGRAMME *PATIENT UNDONE* ABOUT?

In autumn 2017 I was diagnosed with breast cancer, and I started to think very differently about what I'd been doing for 25 years. I thought I'd made up my mind about things like choice and consent, and autonomy – the ability to make decisions for yourself. But I was struck by how frightening I found it to give consent, and I was surprised that things that I'd always really argued for, like copying patients in to letters, could actually be very difficult to bear and might not be as much of an unmitigated good as I thought it was.

CAN YOU TELL US MORE ABOUT YOUR EXPERIENCES OF CHOICE, CONSENT AND AUTONOMY AS A PATIENT?

My experience was that I both wanted that power and struggled with it, all at the same time. It's that contradiction that's at the heart of *Patient Undone* [BBC Radio 4, 16 April, 11am]. There was still a very rational part of me that absolutely believed my body, my choice, my life. I needed information to make decisions.

But there was another bit of me that was frightened, overwhelmed, and emotional. I really didn't want to have anything to do with prognosis, risk-benefit analysis, or



ABOVE: In 2017's heart-wrenching case of Charlie Gard, the boy's parents and doctors disagreed over the best course of action regarding treatment of his genetic disorder, with the High Court eventually getting involved

LEFT: Deborah was treated for breast cancer, a cell of which is visualised here

statistics about dying. I just wanted to stick my hands over my ears. I thought consent and autonomy inherently empowers people, but what I've learned is that it might sometimes make things harder, and that really surprised me.

I thought, 'Well, what does this mean for anybody trying to get consent from a patient? How do we manage to accommodate these different versions of ourselves?'

DID THAT CHANGE OVER THE COURSE OF YOUR TREATMENT?

It settled and changed over time, and there was a rhythm and I got used to things. Again, I hadn't ever really thought deliberately about time and its significance: how you might change over time, and what clinicians can do to recognise that you might feel differently after a month, six months or a year than you do at the beginning.

THAT MAKES IT SEEM LIKE IT WOULD BE HARD TO MAKE ETHICAL GUIDELINES THAT FIT ALL THE PATIENTS AT ALL TIMES.

I came out of this thinking, 'Oh my god, have I spent my career doing a thing that isn't possible?' But I concluded two things: I think it's difficult, but not impossible, and the way to do it is to have a really explicit acknowledgement and discussion of the contradiction, the complexity and the changing nature of patients'

feelings. At the moment we tend to say these are the four elements of valid consent: given by a patient with capacity to make a decision; who is sufficiently informed; gives consent voluntarily; and can withdraw consent at any stage. But we don't talk about emotion and rationality colliding. All of that is implicit rather than explicit, and I think the challenge for me now in my work is to think explicitly about that complexity, even if people aren't talking about it. Especially if they're not talking about it.

DOCTOR-PATIENT COMMUNICATION IS A BIG PART OF THE TREATMENT PROCESS. ARE THERE ETHICAL GUIDELINES GOVERNING COMMUNICATION?

There are oodles and oodles of them. You can't move for guidelines and courses. There are things you can learn, about body language and listening and expressing empathy, but there also has to be a real commitment by both people to make the consultation as effective and supportive as it possibly can be, and that's an attitude that's more difficult to learn or teach.

My surgeon was the person who told me I had cancer. In the programme he talked about the need to get it right, because you've only got one chance at this. As a patient you're hyper sensitive, and I will remember every nuance and every piece of non verbal body language, every word that was spoken, and he recognises that. It's not that he's following good communications guidelines, it's that he goes further and recognises the significance of the conversation, and he cares enough to get it right.

HAVE YOUR PROFESSIONAL VIEWS CHANGED BECAUSE OF YOUR EXPERIENCE AS A PATIENT?

I still think that autonomy is still the cornerstone of Western medical ethics, but I also feel now that autonomy is complex, that you have to attend to the emotional and the rational and the contradictions of both. I think about honesty differently. I still believe in honesty, of course, but I don't think necessarily that being honest means you say everything all at once, and I don't think it necessarily means that you have to put the focus on risk or potential harms.

Now, I could stop teaching everything I teach and just rock up once and say, 'be kind, no exceptions', and that would cover it.

BBC
RADIO



Listen to Patient Undone on 16 April
at 11am on BBC Radio 4.

—
DR DEBORAH BOWMAN (@DeborahBowman)
Deborah is a professor of bioethics, clinical ethics and medical law at St George's University of London.
Interviewed by BBC Science Focus editorial assistant Helen Glenny.

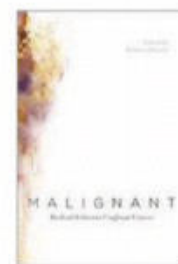
Learn more



ILLNESS

HAVI CAREL
(£21.99, TAYLOR & FRANCIS LTD)

An elegant and thoughtful account of illness by a philosopher who developed a rare lung disease and whose thinking combines moving insights with scholarship, presented in an engaging and accessible style.



MALIGNANT

REBECCA DRESSER
(£25.99, OXFORD UNIVERSITY PRESS)

A group of ethicists who have either had cancer themselves, or loved someone who had cancer, reflect on those experiences and the ways in which their thinking and clinical ethics practice has been changed.



INSIDE THE ETHICS COMMITTEE

bit.ly/ethics_committee

This was the first BBC radio programme Deborah Bowman was involved in. It offers an insight into real clinical ethics cases and how they are discussed and resolved.

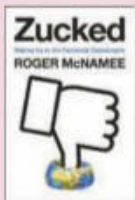
RECOMMENDED

FIND OUT WHAT'S CAUGHT OUR ATTENTION THIS MONTH



WHAT I'M READING

Sara Rigby
ONLINE ASSISTANT



ZUCKED: WAKING UP TO THE FACEBOOK CATASTROPHE

BY ROGER MCNAMEE
(£16.99, HARPER COLLINS)

We've heard a lot of criticisms of Facebook, from its handling of data to its failure to protect vulnerable people and youngsters, but we don't often get to hear the inside story. Roger McNamee, an early investor in Facebook and former mentor to co-founder and CEO Mark Zuckerberg, gives us that privilege in his book *Zucked: Waking Up To The Facebook Catastrophe*.

McNamee tells the story of how he became involved with Facebook and how he came to believe that there is something fundamentally wrong. He describes how Facebook's well-intentioned policies became open to exploitation by groups whose intentions were far less pure, and how Facebook's unwillingness to take responsibility for the content it hosts now presents a threat to democracy. He places all of this into context, describing the historical changes in the political and technological climate that made Facebook what it is today.

Zucked represents McNamee's latest attempt to urge Facebook into action. This book is an enlightening read for everyone who uses Facebook, and especially for anyone who has ever been uncomfortable with how it uses their private data.



WHERE I'M GOING...

James Lloyd
STAFF WRITER

SMOKE AND MIRRORS

WELLCOME COLLECTION, LONDON,
11 APRIL – 15 SEPTEMBER 2019

My Paul Daniels magic set was one of my prized possessions growing up – a box full of delights to impress and dumbfound my friends. Or so I hoped. One birthday party, I decided to perform a few tricks to the assembled throng. It turns out that there are few things more deflating than a room full of kids gleefully crying, "I know how you did that!"



Magic wasn't really my forte, but I still love to watch a good trick. Indeed, there's a deep connection between magic and the human mind – something which is explored in a new exhibition at the Wellcome Collection.

The exhibition looks at what psychologists have learnt from magic, and how our cognitive weaknesses can explain why we're so often taken in by a well-performed trick.

The link between science and magic goes back a long way. When séances and spiritualism became fashionable during the 19th and early 20th Centuries, magicians helped to design scientific experiments to test the psychics' claims. It's a sceptical approach to the paranormal that follows a direct line through to James Randi, Penn & Teller and Prof Richard Wiseman.



WHAT I'M TESTING

Daniel Bennett
EDITOR

AUDIO-TECHNICA ATH M50XBT WIRELESS OVER-EAR HEADPHONES

£170, [AUDIO-TECHNICA.COM](http://audio-technica.com)

They have a 40-hour battery life. That's the only thing you need to know about these Bluetooth headphones. They sound great too, but nothing dulls your enthusiasm for wireless tech than having to charge it every day. After all, what's the point in cutting the cord if you just end up carrying it around with you everywhere?

Usually, more battery life means more weight, but that's not the case here. The M50xBT headphones are light and cosy, despite looking a bit thickset. The chunky design harks back to the original wired headphones popular with sound engineers in the noughties, thanks in part to their articulating arms and ease of repair. But for me, the satisfyingly mechanical build speaks to their durability. They look and feel like they'll handle the knocks and bumps of everyday life.

For a pair of affordable Bluetooth headphones, the audio quality is not far off some of Audio-Technica's more expensive options. Large drivers pump out big, voluminous bass, without washing out the treble or sacrificing much clarity. The only drawbacks were the fiddly buttons on the earcup, and the headphones do get quite warm after several hours of use. That said, you won't find a lot better at this price.





WHAT I'M BROWSING

**Alice Lipscombe-
Southwell**

PRODUCTION EDITOR

ONCE UPON A TRY

[ARTSANDCULTURE.GOOGLE.COM/PROJECT/
ONCE UPON A TRY](https://artsandculture.google.com/project/once-upon-a-try)

For me, one of the joys of visiting a new city is exploring the history of the place and spending a couple of lazy hours wandering around a local museum, perhaps before decamping to a cafe to fill my face with local liqueurs and custardy pastries. But city breaks ain't cheap, and this month my purse strings are pretty tight, so instead I've been settling down in front of the computer screen to engross myself in Google's just-launched *Once Upon A Try*.

It's a massive online exhibition – the largest ever, in fact – where you can explore artworks and collections from NASA, CERN and more than 100 museums around the world. I found myself marvelling over a curated collection of teapots from the 18th Century, and watching videos on the art of bento, before exploring Robert Falcon Scott's hut in Antarctica through Google Street View. But the zoologist in me loved finding out more about unsung female trailblazers of natural history, including Maria Sibylla Merian, who did pioneering research in metamorphosis, and Evelyn Cheesman, an English entomologist who struck out on solo expeditions to collect specimens, exploring areas that others would refuse to visit.

I eventually felt the need to stretch my legs, so I downloaded the *Big Bang* augmented reality app,

developed alongside the exhibition in collaboration with CERN. It's a 360° recreation of the birth of the Universe that you can wander around. It documents the beginning of the Big Bang to the creation of Earth, all narrated by Tilda Swinton.

But the most amazing feature I saw was a short documentary about artist Cai Guo-Qiang. He scorches his canvases by lighting lines of carefully laid gunpowder, but also creates huge outdoor fireworks exhibitions. I'd never seen anything like his bursts of daytime fireworks, coloured by pigment and smoke.

Once Upon A Try is huge. And yes, it's somewhat overwhelming. But it's been split into various sections, like collections, themes, experiments and artists, to make it a little easier to navigate. Seriously, you could lose days in here, and all without having to contend with a budget airline.

ABOVE:
Google's
whizzy new
exhibition lets
you witness
Cai Guo-
Qiang's
incredible
firework
displays

Craft your coffee

COFFEE EXPERT MAT NORTH'S RECOMMENDATIONS ON THE BEST BREWER FOR EVERY BUDGET



AEROPRESS

This single-cup coffee maker is highly regarded in the coffee community. The grounds are immersed in water then rapidly filtered when you push the plunger down. The design's been so successful there's now an Aeropress world championship, and a documentary about its invention. It was created by Alan Adler, who shifted focus from his Guinness World Record-setting Aerobie Frisbees to making a robust, portable, high-quality coffee maker.

£29.99, [AEROPRESS.COM](https://aeropress.com)



CLEVER COFFEE DRIPPER

This is like a pour-over, but it's also got a little bung underneath, which makes it an immersion method of brewing. When it's done you put it on top of your mug, the bung pushes out, and the paper filter removes all the fine particles.

£20, [VARIOUS COFFEE RETAILERS](https://www.variouscoffee.com)



DECENT ESPRESSO DE1PRO

The Decent coffee machine lets you control almost everything. It's app-controlled and open source, so you can write your own coffee-making programmes. There's even a chat group for owners to share what they're making.

FROM \$2,499 (£1,900 APPROX), [DECENTESPRESSO.COM](https://decentespresso.com)



MOCCAMASTER HOME BREWER

This home filter coffee machine, hand-made in the Netherlands, can pump out 10 cups in six minutes. It gets the details spot-on: it heats the water to the perfect 92-96°C range, and its hot plate keeps coffee at 80-85°C after it has been brewed.

£192, [MOCCAMASTER.EU](https://moccamaster.eu)



SAGE BARISTA EXPRESS

When you start spending the big bucks on espresso machines, you're paying for more control. This has an 18-setting burr grinder, adjustable temperatures, and a manual mode for controlling how much coffee is dispensed.

£599.99, [SAGEAPPLIANCES.COM](https://sageappliances.com)

Troubleshoot

COFFEE BREWING AT HOME



ACCORDING TO EXPERT MAT NORTH, BREWING COFFEE IS A SCIENCE EXPERIMENT; YOU JUST NEED TO KNOW WHICH VARIABLES TO MANIPULATE

HOW CAN WE USE SCIENCE TO IMPROVE OUR COFFEE?

Making coffee is a chemical process. We have our solvent, coffee, we have our solute, water, and we create a solution. Within that, there are a myriad of variables that we can control, but there are four key ones that we really need to get a handle on.

Water is the first. Ninety eight per cent of every coffee you drink is going to be water; it carries the bulk of the flavour. The process of drawing out chemical compounds, what we call 'extraction', is really just osmosis. Positively charged ions from the minerals in the water latch on to negatively charged ions that are the acids and sugars, and physically draw them out. So by tuning your mineral content, you can tune what kind of acids and flavour compounds you draw out. My favourite weird acid that you get in coffee is isovaleric acid, which gives the smell and taste of blue cheese or feet.

YIKES. SO WHAT SHOULD WE DO TO OUR WATER TO IMPROVE OUR COFFEE?

Always filter your water. You can use tap water, but you'll be fighting a difficult battle, especially in hard water areas. Water contains an awful lot of calcium carbonate, which mutes acidity. If you have a lot of bicarbonate in there you're

going to bring back any acidity that you extract, and make it taste kind of chalky and flat.

WHAT'S THE NEXT IMPORTANT VARIABLE?

Then it's your ratio of coffee to water. The Speciality Coffee Association recommends 60g of dry coffee to a litre of water. We use that as a starting point because it gives us a balance between strength and extraction, so you get a brew that's not too strong, not too weak, not too bitter.

GREAT. WHAT ELSE IS IMPORTANT?

Temperature. Solvents are more efficient when they're hot. You can brew coffee with cold water, it just takes a lot longer. If you use boiling water, you've got to work fast because you're going to extract things very quickly. Between 90°C and 96°C is the perfect water temperature.

Then there's time, which is more method specific. If you're brewing in an Aeropress or some kind of filter brewer, you want some contact time with the coffee grounds. Acids are volatile compounds and are extracted quite quickly, but a lot of the more stable compounds sugars for example take longer to extract.

Grind size is the last important variable. A larger grind size will extract more slowly, so if your brew tastes harsh, bitter and ashy (what's known as over extracted), then using a coarser grind size will help rectify that. Likewise, if your coffee tastes overly acidic or sour (what's known as under extracted) using a finer grind will help. The goal should always be a balance between acidity, bitterness and natural sweetness.

SO WHAT SHOULD WE DO TO IMPROVE THE COFFEE WE MAKE AT HOME?

First of all, fresh beans, which means buying less more often. Even whole beans go stale. Or, if it's more convenient, freeze your beans. It's an excellent way of preserving flavours and aromas. You can grind from frozen too.

Use freshly ground coffee. All of the aromatics and the acid compounds in coffee are volatile, and they dissociate very quickly. When you grind your beans, you create a lot more surface area for aromatic flavours to be taken away.

×

“My favourite weird acid that you get in coffee is isovaleric acid, which gives the smell and taste of blue cheese or feet”

It's important to use scales. At home, I use a £3 set of kitchen scales. I weigh out the coffee, I grind it, and I put it into my filter brewer. I use a Clever Coffee Dripper. I know that my mug is 300ml, so I use 20g of coffee, 300ml of water, and I leave it for two minutes. Using scales is one of the biggest changes you can make.

Then make sure you're boiling water fresh. The more times you boil water the more you evaporate it off, increasing the mineral content. A few kettles now will allow you to set temperature, but if you don't have one of those, just leave the water in the kettle for 60 to 90 seconds, which will allow it to cool down by 4°C or 5°C. The more water in there the slower it will cool, so leave it 60 seconds if you've half filled the kettle, or 90 if it's full.

This all sounds complex, but making good coffee at home is easy to do; just find a method that works for you. Most importantly, pick a method that's simple when you're tired in the morning. If it's not easy to do at 4am and your kid has woken you up, it's not worth it.

MAT NORTH (@MatNorth)

Mat is the owner of Full Court Press, a speciality coffee shop in Bristol, and the author of *Coffee: A Modern Field Guide*. **Interviewed by BBC Science Focus editorial assistant Helen Glenny.**

DISCOVER MORE

SQUEEZE EXTRA JUICE OUT OF THE TOPICS IN THIS ISSUE OF *BBC SCIENCE FOCUS* WITH THESE BOOKS, WEBSITES AND SHOWS

Masters of disaster p44

MORE OR LESS: ARE NATURAL DISASTERS ON THE RISE?

In this episode of the BBC Radio 4 programme, the *More Or Less* team tries to find out if natural disasters are becoming more frequent.

bit.ly/disasters_rise

FLOWAVE OCEAN ENERGY RESEARCH FACILITY

Watch a video of Edinburgh University's Flowave in action.

bit.ly/flowave

The walk of prehistoric life p52

THE RISE AND FALL OF THE DINOSAURS

BY STEVE BRUSATTE (£9.99, PAN MACMILLAN)

In this accessible book, dinosaur expert Steve Brusatte takes us through the real story of how the dinosaurs came to dominate the planet and looks at the legacy they left behind.

TETRAPOD ZOOLOGY

Darren Naish and John Conway devote this regular podcast to discussion, research, discovery and speculation regarding amphibians, reptiles, birds and mammals, and all of their extinct relatives.

tetzoo.com/podcast

THE CURIOUS CASES OF RUTHERFORD & FRY: THE TINIEST DINOSAUR

In this episode of the popular BBC Radio 4 programme, Hannah Fry and Adam Rutherford find out which is the smallest dinosaur.

bit.ly/tiny_dino

What if the Big Bang was not the beginning? p70

THE INFINITE MONKEY CAGE: BEFORE THE BIG BANG

In this episode of *The Infinite Monkey Cage*, Brian Cox and Robin Ince find out what happened before the Big Bang.

bit.ly/monkey_big_bang

THE INFINITE MONKEY CAGE: HOW WE MEASURE THE UNIVERSE

In this episode of *The Infinite Monkey Cage*, Brian Cox and Robin Ince find out how we measure the Universe.

bit.ly/monkey_universe

COSMIC INFLATION THEORY FACES CHALLENGES

This article by Anna Ijjas, Paul J Steinhardt and Abraham Loeb was published in *Scientific American* in February 2017.

bit.ly/cosmic-inflation-SA

UNIQUE FINGERPRINTS OF ALTERNATIVES TO INFLATION IN THE PRIMORDIAL POWER SPECTRUM

This paper was published earlier this year by Xingang Chen, Abraham Loeb and Zhong-Zhi Xianyu.

bit.ly/inflation_alternative

Is addiction on the rise? p78

TREATING ADDICTION AGAINST ALL ODDS

In this TEDMed talk, Dr Henrietta Bowden-Jones gives her motivation for setting up the UK's first problem gambling clinic.

bit.ly/bowden_jones

THE DIGITAL HUMAN: INSATIABLE

In episode of BBC Radio 4's *The Digital Human*, presenter Aleks Krotoski investigates why it's so hard for us to stop carrying out behaviours, even when we've had enough.

bit.ly/digital_insatiable

FOUR THOUGHT: UNDERSTANDING DRUG ADDICTION

In episode of BBC Radio 4's *Four Thought*, Hanna Pickard says that we need to understand *why* people become addicted to drugs, rather than just labelling them as reckless or hedonists.

bit.ly/four_thought

INSIDE SCIENCE: SCIENCE OF ADDICTION

In this episode of *Inside Science*, Adam Rutherford investigates the science of addiction.

bit.ly/bbc_sounds_addiction

Q&A p85

NATURE'S WEIRDEST CREATURES: THE BOBBIT WORM

In this clip from BBC One's *Blue Planet II*, you can see the bobbit worm in action.

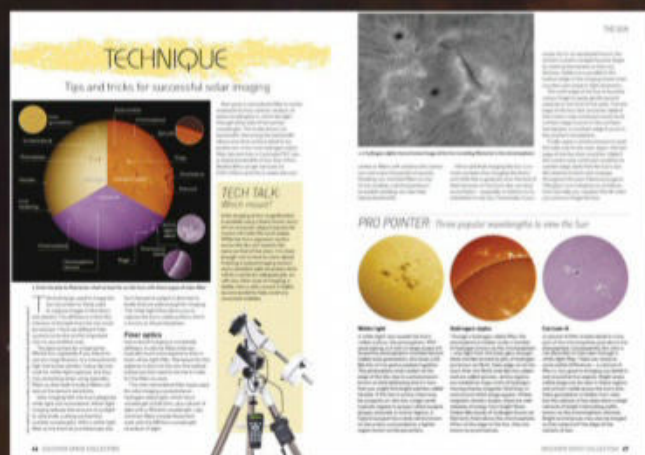
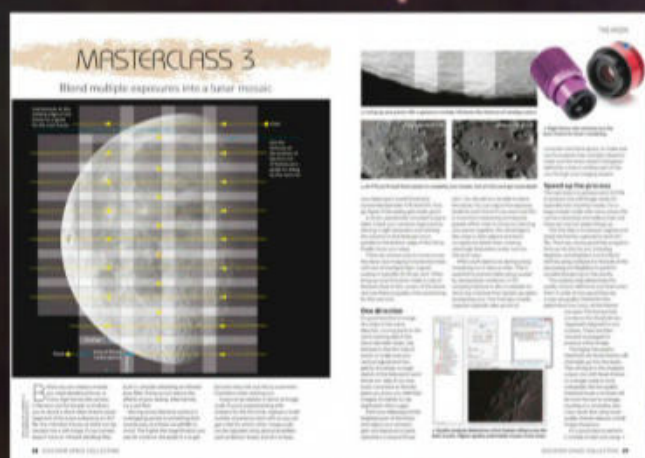
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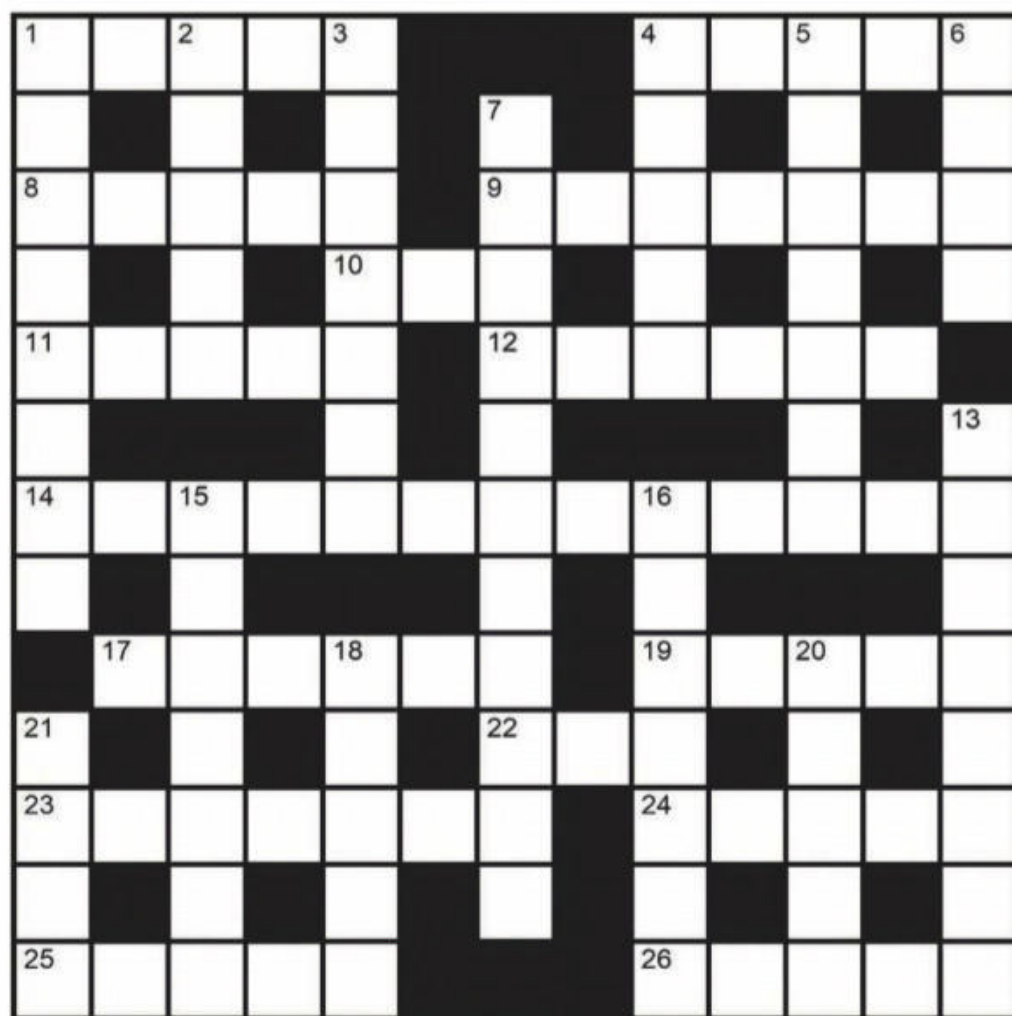
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CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 1 High-level programming language is simple (5)
 4 Wrapped a chain around villa (5)
 8 Fruit produces a painful affliction (5)
 9 Understanding French? (7)
 10 Drink of character, say (3)
 11 Country needs form of energy – any form (5)
 12 Cloth right inside implement (6)
 14 Second person's admiration for clerical address (4,9)
 17 Reportedly, emblem used by a drummer (6)
 19 Prohibit the cooking of bread (5)
 22 Swimming pool missing last cover (3)
 23 Space next to cute-sounding bathroom (2,5)
 24 Apply pressure in the hallway (5)
 25 Hurry, as the order has changed (5)
 26 Broadcast orally without liberal prince, say (5)

DOWN

- 1 Injury makes British servant join back of queue (5,3)
 2 Betting on getting round some cutlery (5)
 3 Mythical creature is about managing nature (7)
 4 The same two dots (5)
 5 Is adolescent able to find food hall? (7)
 6 Copy kiss on top (4)
 7 Hated being forced to visit top passage in Mojave Desert (5,6)
 13 Bleat about fellow being involved in disloyalty (8)
 15 Odysseus, in novel form (7)
 16 Sieve right for comic book villain (7)
 18 Barks audibly for some material (5)
 20 Robert seen on his beat (5)
 21 Network of same shapes (4)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW

Please be aware the website address is case-sensitive.

TOM RUEN/ESO

COVER STORY

PLANET NINE

This hypothetical planet could be lurking in the outer reaches of our Solar System, disrupting the orbits of objects beyond Neptune. But can we find it?



PLUS

SHOULD MEDICINE BE GENDERED?

Men and women have completely different biologies, so why are we prescribed the same treatments?

DEMENTIA ON THE MENU

Michelin-starred chef employs an entire restaurant team with dementia, and that's just for starters.

ON SALE 1 MAY



A SCIENTIST'S GUIDE TO LIFE

DIGITAL LIVING

MODERN LIFE CAN FEEL LIKE A
CONSTANT BARRAGE OF DIGITAL
STIMULI. COGNITIVE SCIENTIST
ANNA COX TELLS US HOW WE CAN
NAVIGATE OUR WAY THROUGH IT



CAN TECHNOLOGY HELP ME WITH MY WORK/LIFE BALANCE?

Often people find it hard to switch off from work when their phones keep them connected to the office. One option is to set up different email apps so you're not looking at work stuff in the evening. We found that people who did this felt they had a better work/life balance and reported feeling less stressed two months later. Other helpful strategies include turning off notifications, or removing your smart watch once you get home. It's about rethinking how you use your technology so you're in control, not the other way around.

HOW OFTEN SHOULD I BE CHECKING MY EMAIL?

Emails can be a big distraction. We ran a study where people either responded to their emails as they came in, or tried to just check them once a day. Doing the latter was difficult, but people did manage to reduce the number of times they checked from eight to three. They found they became more efficient at dealing with their emails and less distracted overall.

HOW DO I STOP MYSELF GETTING DISTRACTED BY CAT VIDEOS?

It's not just cats. We've all experienced clicking away from one screen to find a

piece of information, only to be totally side-tracked by emails, social media and information on the internet. As part of a study, we built a tool that sits in your browser and measures how long you switch away for. People who used it found it helped them to be less distracted and work more efficiently. [The tool is not yet publicly available.]

SHOULD I WORRY ABOUT THE AMOUNT OF TIME THAT I SPEND LOOKING AT A SCREEN?

People do worry about screen time, but it's important to think about *what* you are doing rather than the total time. Are you watching films? Reading books? Or posting on social media? Keeping an eye on your usage – by opting to receive regular updates, or downloading a monitoring app – can help you become less stressed about it.

ARE VIDEO GAMES BAD FOR YOU?

Not necessarily. Our research suggests that playing video games can help people feel less stressed. There are many reasons for this. If you're playing with other people then you have the opportunity to make social connections. Video games give people the chance to experience challenges and overcome them, so you have this sense of mastery, and while you're engaged in playing, it's really hard to be worried about work. You can see how it's a wonderful distraction.

MY CHILDREN BECOME TOTALLY NON-RESPONSIVE WHEN THEY'RE PLAYING VIDEO GAMES. HOW CAN I GET THEIR ATTENTION?

If you want to call your kids for dinner, don't just shout 'dinner's ready'. People playing games become very focused. We've tested various distractions and the one thing that works is saying their name. If they don't respond, they still heard you and *then* you can get mad at them. **SF**

NEED TO KNOW...

1

Try to check work
email just once
a day.

2

Switch off
notifications and
separate your work
and life apps.

3

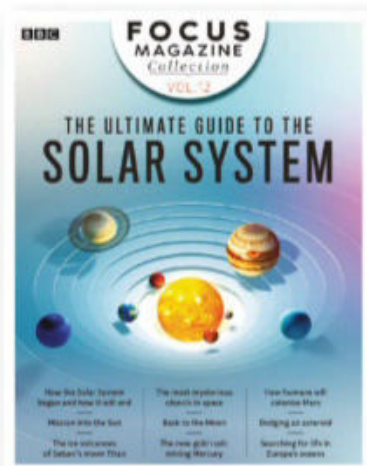
Screens and
gaming can be
good. Chill out
and enjoy.

ANNA COX
(@AnnaCox_)
Anna is professor of
human-computer
interaction at
University College
London.
Interviewed by
Dr Helen Pilcher.

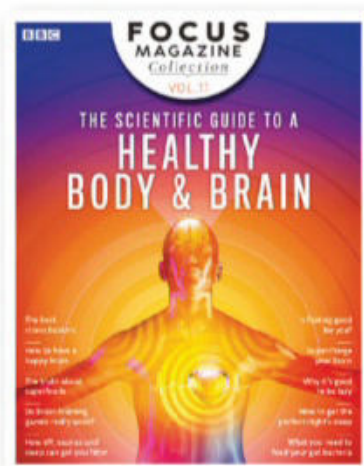
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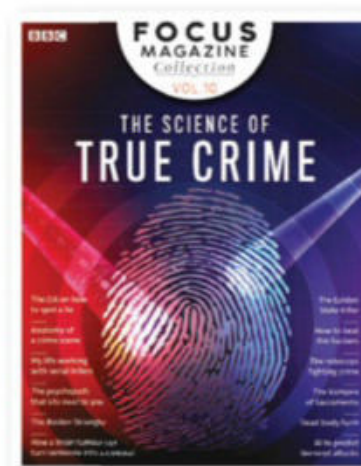
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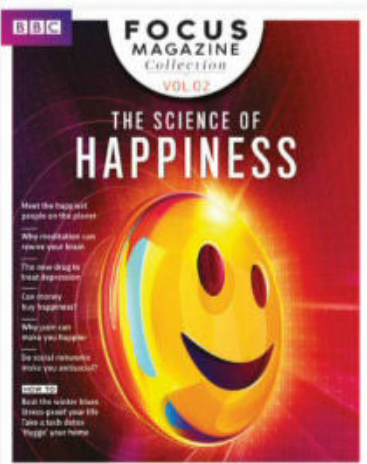
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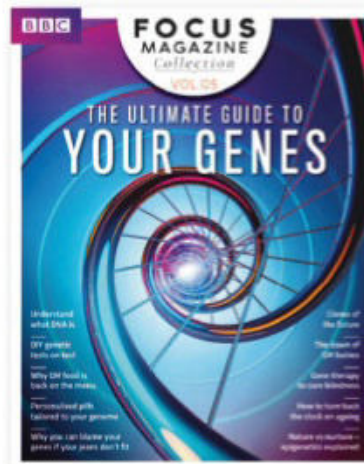
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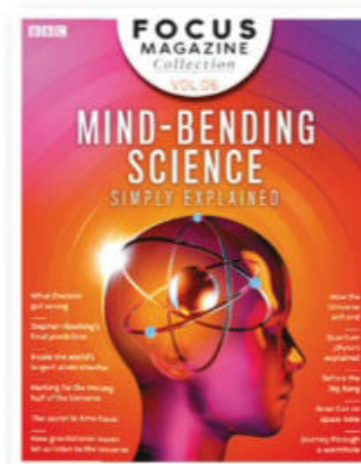
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